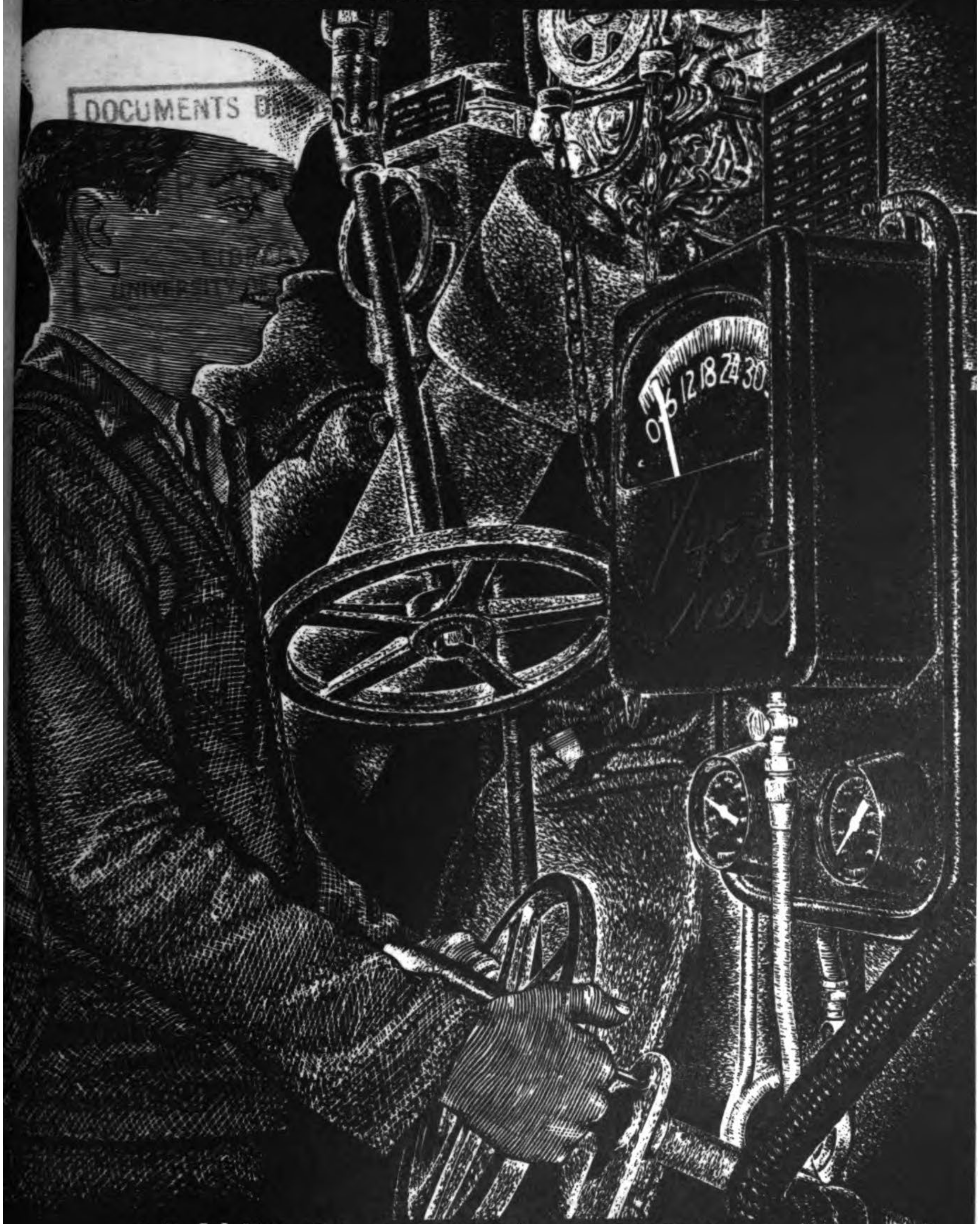
BOILERMAN 3 & 2



NAVY TRAINING COURSES

NAVPERS 10535-C

BOILERMAN 3 & 2

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NAVPERS 10535-C

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PREFACE

This book is a complete revision of the *Boilerman 3 & 2* training course which was first published in 1950 and was reprinted in 1951 and 1953 with minor changes and corrections. It is written for enlisted men of the Navy and the Naval Reserve who are preparing for advancement to the rates of Boilerman 3 and Boilerman 2. Study of this text should be combined with practical experience and with study of the appropriate references listed in chapter 1.

The qualifications for advancement in the Boilerman rating are given in appendix II of this book. Since the examinations for advancement in rating are based upon these qualifications, it is suggested that you refer to them frequently.

As one of the NAVY TRAINING COURSES, this book has been prepared by the U. S. Navy Training Publications Center for the Bureau of Naval Personnel, with technical assistance from the Bureau of Ships, the U. S. Naval Engineering Experiment Station, and the U. S. Naval School Boilermen, Philadelphia.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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Boilerman 3 & 2

READING LIST

NAVY TRAINING COURSES

Blueprint Reading (Chapters 1–5), NavPers 10077
Basic Hand Tool Skills, NavPers 10085
(metal working skills only)

OTHER PUBLICATIONS

BuShips *Manual* (Chapters 51, 53, 55, 56, 88, Sec. III)

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education officer.* A partial list of these courses applicable to your rate follows:

Number	Title
MA 779	*Blueprint Reading*
MB, CB 799	*Power Plant Engineering*

*"Members of the United States Armed Forces Reserve Components when on active duty are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more; or if they have been on active duty for a period of 120 days or more regardless of the time specified in the active duty orders."

CHAPTER 1

ADVANCEMENT TO PETTY OFFICER

The current qualifications for advancement in the Boilerman rating require that the applicant be able to operate all types of marine boilers and fireroom machinery; transfer, test, and take inventory of fuels and water; and maintain and repair boilers, pumps, and associated machinery.

In order to understand the exact requirements for advancement to Boilerman 3 or Boilerman 2, you should make a careful study of the Boilerman qualifications listed in the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Rev.). The portion of this *Manual* which deals with Boilerman qualifications is given in appendix II of this training course.

As you study the qualifications for advancement in rating, remember that the qualifications listed represent the MINIMUM requirements for each rate. Compare the required qualifications with the qualifications you now possess. If you doubt your ability to meet any of the requirements, study appropriate training courses, manufacturers' instruction books, applicable chapters of BuShips *Manual*, and any other available reference material which will be of help to you.

In addition to reading and studying, you should check yourself out on equipment, to make sure that you can meet the practical factor requirements. Extensive review of

both written material and practical factors will be necessary before you can meet the requirements for the next higher rate.

GREATER RESPONSIBILITY

As you know, any advancement in rate requires a corresponding increase in knowledge and skill, in willingness to assume responsibility, and in ability to lead men. With greater authority comes greater responsibility. As you advance in the Boilerman rating, your military duties will become more important. You will have an increasing responsibility for showing other men what to do and how to do it, and for checking their work.

A detailed consideration of the military requirements for each rate is beyond the scope of this training course. Military duties and requirements are discussed in other training courses and manuals, which are listed later in this chapter. For the most part, this training course is concerned with information related to your professional (technical) duties.

Every petty officer must, of course, be a technical specialist in his own field. As you advance in your rating, however, it will become increasingly important for you to understand the duties and responsibilities of men in related ratings, and to understand how the entire Engineering Department functions. You must learn to know what work is done, and what equipment is used, by the Electrician's Mate, the Machinist's Mate, the Pipe Fitter, the Machinery Repairman, the Metalsmith, the Damage Controlman, and personnel of other Engineering and Hull group ratings. Although it is true that many maintenance and repair jobs can be properly handled within your own division, some jobs will require skills and equipment found only in another division. You must, therefore, learn to work with the rest of the Engineering Department, and to utilize the skills and technical knowledge of other ratings when necessary.

As a petty officer, you must assume a great deal of responsibility in the matter of SAFETY. You must observe the safety

precautions relating to the operation and maintenance of all fireroom machinery, and you must make it your responsibility to know the procedures to be followed in the event of fireroom casualty. Safety precautions should be posted at each piece of equipment. Safety precautions are covered in the applicable chapters of BuShips *Manual*, in some manufacturers' instruction books, and in *United States Navy Safety Precautions*, OPNAV 34 P1.

SOURCES OF INFORMATION

Since this training course does not include information on military requirements, and since the information it offers on professional requirements cannot be all-inclusive, you will need additional sources of information. A working list of material to be studied by enlisted personnel seeking advancement in rating is given in *Training Courses and Publications for General Service Ratings*, NavPers 10052. This publication is revised and brought up to date from time to time, so be sure to consult the most recent edition.

References on Military Requirements

The basic reference on military requirements is the *General Training Course for Petty Officers*, NavPers 10055. A knowledge of the material contained in this book is mandatory for all petty officers of all ratings. Further information on military requirements will be found in the other publications listed in the current *Training Courses and Publications for General Service Ratings*, NavPers 10052.

Reference on Professional Requirements

A great deal of information which will aid you in meeting the professional (technical) requirements for advancement is contained in the instruction books prepared by the manufacturers of the various units of machinery. In addition, BuShips *Manual* contains valuable information on what is considered the best engineering practice in the operation

and maintenance of most of the machinery with which you will be working.

The current edition of *Training Courses and Publications for General Service Ratings* should be consulted for other references concerning the professional (technical) qualifications for advancement. The following list of references includes some of the items listed in the above-named publication, and also includes some other books which may be helpful to you as sources of basic information:

Basic Hand Tool Skills, NavPers 10085
Basic Machines, NavPers 10624
Blueprint Reading, NavPers 10077
Fireman, NavPers 10520–A
BuShips *Manual*,

Chapter 47	Pumps
Chapter 48	Piping
Chapter 50	Auxiliary steam turbines
Chapter 51	Boilers
Chapter 53	Blowers
Chapter 55	Fuel oil stowage and equipment
Chapter 56	Boiler feed water and feed water apparatus
Chapter 87	Mechanical measuring instruments
Chapter 88	Damage control (Section III, Engineering casualty control)
Chapter 95	Gaskets and packing

In addition to these references, you may find it useful to consult the Navy Training Courses prepared for other Group VII (Engineering and Hull) ratings. Reference to these training courses will add to your knowledge of the duties of other men in the Engineering Department.

SCOPE OF THIS TRAINING COURSE

This training course is designed to help you to meet the professional (technical) requirements for advancement to Boilerman 3 and Boilerman 2. Chapters 2, 3, and 4 deal

with boilers, boiler fittings, and control instruments. Chapters 5, 6, and 7 cover auxiliary turbines and the pumps and forced draft blowers which are, for the most part, driven by steam turbines. In chapters 8 and 9 consideration is given to boiler water and feed water. Fuel oil systems are covered in chapter 10. The next two chapters, 11 and 12, take up fireroom operations and fireroom casualty control. Chapter 13 contains information on boiler maintenance and repair. In chapter 14, valves, pipe fittings, and piping are discussed. Chapter 15 details the duties of the oil and water king.

In general, you will find that information regarding specific units of machinery discussed in this training course is presented in the following order: first, the theory and construction of the equipment; second, the practical operating instructions; and third, the maintenance and repair work required to keep the machinery in good operating condition. In addition, you will find information on tests and inspections and on safety precautions, where such information is applicable.

In order to make the most effective use of this training course, you should refer frequently to the qualifications for advancement in rating which are given in appendix II.

CHAPTER 2

BOILERS

Most naval vessels, with the exception of submarines, some auxiliaries, and some destroyer escorts, are steam driven. Steam serves the essential purpose of carrying energy to the engines. The fuel burned in the boiler furnace is the SOURCE of heat energy; the steam generated in the boilers is the MEDIUM by which heat energy is carried to the turbines, where it is converted into mechanical energy. Mechanical energy propels the ship and provides power for many vital services—steering, lighting, ventilation, cooking, heating, refrigeration, the operation of electrical and electronic devices, and the loading, aiming, and firing of the ship's guns. On steam-propelled ships, Diesel engines are usually used only to power emergency equipment.

As a Boilerman, you are directly concerned with the generation of steam. You must have a thorough knowledge of the design, construction, and operation of boilers used on naval vessels, and you must understand the function and operation of the other component parts of the steam plant. In this chapter we will take up the principles of steam generation; standard terminology used in discussion of naval boilers; design and operational limitations upon boiler capacity; types of boilers; boiler construction; refractories; furnace construction; new types of boiler installations; and auxiliary boilers.

STEAM GENERATION

In order to generate steam, it is necessary to heat water to its boiling point and then to add a sufficient amount of heat to convert the boiling water into steam. The heat required to change boiling water into steam at the same temperature as the boiling water is called the LATENT HEAT OF VAPORIZATION. When steam condenses back to water (at the boiling point) an equal amount of heat is given off; in this case, it is called the LATENT HEAT OF CONDENSATION. The amount of heat required to convert boiling water to steam (or, on the other hand, the amount of heat given off when steam is condensed back to water at its boiling temperature) varies with the pressure under which the process takes place.

There are definite pressure-temperature relationships involved in the generation of steam. The boiling point of water is 212° F at sea level, where the atmospheric pressure is 14.7 psi. At high altitudes, where atmospheric pressure is reduced, water boils at a lower temperature. If pressure is increased, the boiling point of water is raised accordingly. In a boiler operating under pressure of 600 psig, water boils at 489° F. Thus, the boiling point of water is determined by the pressure.

It is important to note that the temperature of steam is determined by the temperature at which the water boils, as long as the process is taking place in a closed vessel or in a closed system such as a boiler. As long as the pressure remains constant, steam which is in contact with the water from which it is being formed must remain at the same temperature as the boiling water. Thus, in a boiler operating under pressure of 600 psig, the temperature of the steam in the steam drum must be 489° F—the same temperature as the boiling water.

The steam in the steam drum is known as SATURATED STEAM—that is, it is steam which has not been heated above the temperature of the water from which it was generated. As a matter of fact, it is impossible to raise the temperature

of saturated steam as long as it is in contact with the water from which it is formed. However, the steam can be heated above its saturation temperature if it is first drawn off into another vessel, where it is no longer in contact with the water, and additional heat is applied. Steam which has been heated above its saturation temperature is known as SUPERHEATED STEAM; and the device which allows this extra heat to be added to the steam is known as a SUPERHEATER. The amount by which the temperature of superheated steam exceeds the temperature of saturated steam at the same pressure is known as the DEGREE OF SUPERHEAT. For example, if saturated steam at a pressure of 600 psig and a saturation temperature of 489° F is superheated to 789° F, its degree of superheat is 300 degrees.

Almost all naval propulsion boilers are equipped with superheaters. Superheated steam has many advantages over saturated steam for use in propulsion machinery. Because it is dry, it causes relatively little corrosion or erosion of piping and machinery. Also, it does not conduct heat as rapidly (and therefore does not lose heat as rapidly) as saturated steam. The use of superheated steam for propulsion purposes greatly increases the overall efficiency of the plant, and this increased efficiency results in substantial savings in fuel consumption and in space and weight requirements.

It should be noted, however, that most auxiliary machinery is designed to operate on saturated steam. Reciprocating machinery, in particular, requires saturated steam for the lubrication of internal moving parts of the steam end. Naval boilers, therefore, are designed to produce both saturated and superheated steam.

THE STEAM-WATER CYCLE

In addition to knowing how steam is generated, you must know what happens to it after it leaves the boiler. One of the best ways to learn about the steam plant on your own ship is to trace the path of steam and water, starting from

the boiler and leading back to the boiler again. The steam-water cycle shown in figure 2–1 contains all the essential components of a modern shipboard steam plant. The steam is led from the steam drum, through the superheater, and then to the turbines, where the heat energy of the steam is converted into mechanical energy. The pressure and temperature of the steam drop as the steam expands through the turbine stages and exhausts into the main condenser. In the condenser, the steam is cooled and condensed into water as it comes in contact with tubes through which sea water is flowing. The condensed steam (condensate) is then pumped through the air ejector condenser to the deaerating tank, where it is heated and deaerated. The condensate (which is now, properly speaking, feed water) is pumped by the feed booster pump to the feed pump, and from there it goes into the economizer of the boiler, where it is further heated before it goes back into the steam drum again. As shown in figure 2–1, additional feed water is brought into the condenser to replace any water which is lost from the system.

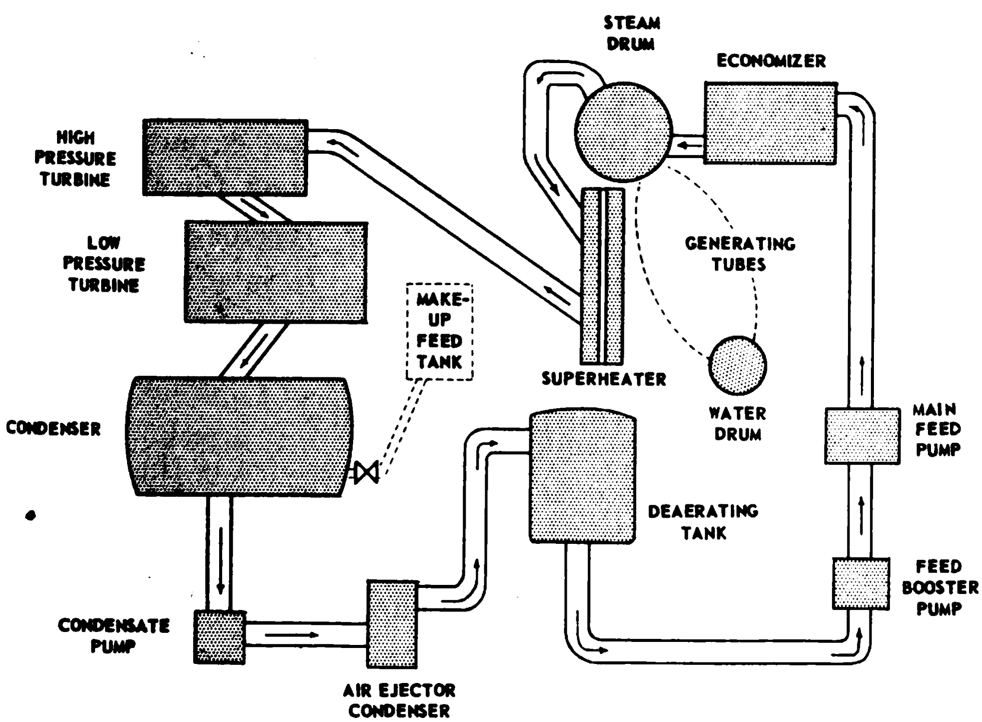


Figure 2–1.—Basic steam-water cycle.

BOILER DEFINITIONS

It is important to know the exact meaning of the standard terms used in discussion of naval boilers. The following definitions have been established for the purpose of ensuring uniform use of terms throughout the service.

FIREROOM and BOILER ROOM.—A compartment which contains boilers and the station for operating them is called a FIREROOM. A compartment which contains boilers but which does not contain the operating station is called a BOILER ROOM.

BOILER OPERATING STATION.—The station from which a boiler or boilers are operated is referred to as a boiler operating station. This term is used most frequency to describe the compartment from which bulkhead-enclosed boilers are operated.

BOILER EMERGENCY STATION.—The boiler emergency station is so located that, in the event of trouble, the Chief Boilerman on watch may proceed with minimum delay to any fireroom, boiler operating station, or boiler room.

BOILER FULL-POWER CAPACITY.—The total quantity of steam required to develop contract shaft horsepower of the vessel, DIVIDED BY the number of boilers installed, gives boiler full-power capacity. The quantity of steam is given in pounds of water evaporated per hour. Full-power capacity is indicated in the manufacturer's instruction book for each boiler.

BOILER OVERLOAD CAPACITY.—Boiler overload capacity is specified in the design of the boiler. It is given in terms of steaming rate or firing rate, depending upon the individual installation. Boiler overload capacity is usually 120 percent of boiler full-power capacity.

OPERATING PRESSURE.—Operating pressure is the pressure at the final outlet from a boiler, after steam has passed through all baffles, dry pipes, superheaters, etc., when the boiler is steaming at full-power capacity. Operating pressure is specified in the design of the boiler, and is given in the manufacturer's instruction book. Under actual operating conditions, when the boiler is steaming at less than full-

power capacity, the pressure at the superheater outlet will vary from the specified operating pressure, provided a constant drum pressure is maintained.

Steam drum pressure.—Like operating pressure, steam drum pressure is specified in the design of a boiler and is given in the manufacturer's instruction book. Steam drum pressure is the pressure which must be carried in the boiler steam drum in order to obtain the required pressure at the turbine throttles, when steaming at full-power capacity. Ordinarily, the designed steam drum pressure is carried for all steaming conditions.

Designed pressure.—Designed pressure is usually 103 percent of steam drum pressure.

Total heating surface.—The total heating surface of any steam generating unit consists of that portion of the heat transfer apparatus which is exposed on one side to the gases of combustion and on the other side to the water or steam being heated. Thus the total heating surface equals the sum of the generating surface, the superheater surface, and the economizer surface.

Generating surface.—The generating surface is that portion of the total heating surface in which the fluid being heated forms part of the circulating system. This surface is measured on the flue-gas side. The generating surface includes the boiler tube bank, water walls, water screens, and water floor (when installed and not covered by refractory).

Superheater surface.—The superheater surface is that portion of the total heating surface where the steam is heated after leaving the boiler steam drum. This surface is measured on the flue-gas side.

Economizer surface.—The economizer surface is that portion of the total heating surface where the feeding fluid is heated before entering the generating system. This surface is measured on the flue-gas side.

Steaming hours.—The term steaming hours includes the time during which the boiler has fires lighted for raising steam and during which it is generating steam. Steaming

hours does NOT include time during which fires are not lighted in an oil-fired boiler.

BOILER LIMITATIONS

The maximum rate at which a boiler can generate steam defines the CAPACITY of the boiler. The rate of steam generation is usually expressed in pounds of water evaporated per hour. The capacity of any boiler is limited by three factors which have to do both with the design of the boiler and with its operation.

First, steam generation in a boiler is limited by the designed maximum firing rate—that is, the maximum amount of fuel that can be burned properly and efficiently. This limitation is called the END POINT FOR COMBUSTION.

Second, there is the END POINT FOR MOISTURE CARRY-OVER. The rate of steam generation cannot be increased beyond the point at which there is excessive moisture carry-over from the staturated steam outlet. In general, naval specifications limit the allowable moisture content of steam leaving the saturated steam outlet to one-quarter of one percent.

Third, there is the END POINT FOR WATER CIRCULATION. The rate of steam generation cannot be increased beyond the point at which the amount of water descending is insufficient to balance the amount of water and steam ascending.

Boilers are so designed that the end point for combustion occurs at a lower rate of steam generation than the end point for moisture carry-over, and the end point for moisture carry-over occurs at a lower rate of steam generation than the end point for water circulation. Since the end point for combustion occurs FIRST, it is the ONLY end point which can actually be reached in a properly designed and properly operated boiler.

End Point for Combustion

The process of burning fuel oil in a boiler furnace involves three steps: (1) heating the oil to the correct temperature for atomization, (2) forcing the oil into the furnace under

pressure, through atomizers which break up the oil into a foglike spray, and (3) forcing air into the furnace under pressure, in such a way that it mixes thoroughly with the oil spray.

The amount of fuel which can be burned properly and efficiently in a boiler is limited primarily by the amount of air which can be forced into the furnace. (The volume and shape of the furnace, and the capacity of the burner apparatus to mix the air with the fuel, are also limiting factors.) The end point for combustion is reached when the maximum amount of air which can be forced into the furnace is insufficient for complete combustion of the fuel. Therefore, if the end point is actually reached, the smoke in the uptakes will be black because it will contain particles of unburned fuel.

End Point for Moisture Carry-Over

Moisture in steam leaving the boiler is likely to cause corrosion of piping and machinery and erosion of internal parts of engines, piping, and fittings. In addition, moisture carried over in the steam may contain insoluble matter which, if deposited in superheater tubes, may form an insulating scale. Similarly, scale may be formed on turbine blades and on other machinery parts, and may in some cases cause unbalance of rotating parts. It is very important, therefore, to prevent excessive moisture carry-over from the boilers.

As the evaporation rate is increased, the the amount of moisture carried over is also increased. In modern naval boilers, the problem of moisture carry-over is complicated by the use of high steam pressures. As pressure increases, the density of the steam increases proportionately, so that a given volume of steam at a high pressure can carry with it more moisture than the same volume of steam at a lower pressure. If the end point for moisture carry-over is exceeded, the damage to machinery and equipment is likely to be extensive even if not immediately apparent.

In modern boilers, various arrangements of baffles, separators, and screens are installed in the steam drum to sep-

arate the moisture from the steam before the steam enters the dry pipe. These devices are classified as internal boiler fittings, and are taken up in chapter 3.

End Point for Water Circulation

In water-tube boilers, the water and steam circulate through one or more closed circuits formed by the drums, tubes, and headers. When the boiler is lighted off, the water in the tubes which receive the most heat becomes less dense than the water in the cooler tubes. Because of this difference in density, the heated water and steam rise, and the cooler water falls; and thus a continuous circulation is set up, as shown in figure 2–2.

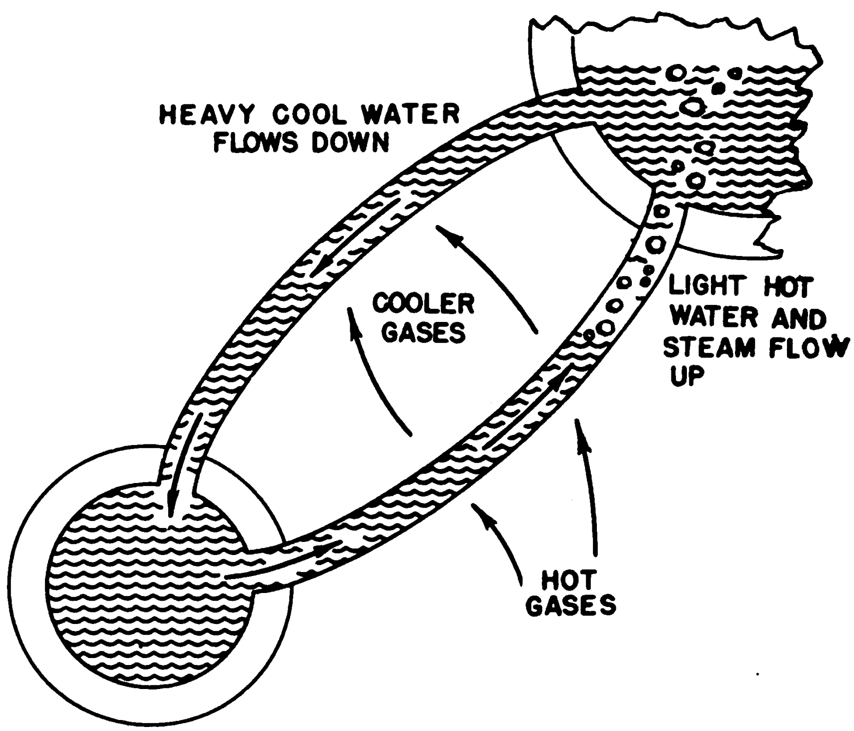


Figure 2–2.—Water and steam circulation.

As the firing rate is increased, the amount of heat which is transferred to the tubes is also increased. A greater number of tubes carry the upward circulation of water, and fewer tubes are left for the downward flow. As the combustion rate is increased still further, more and more tubes become

generating tubes, and still fewer are left for the downward flow of water. Eventually a point is reached where the amount of water descending is insufficient to balance the amount of water and steam ascending, and some tubes near the furnace are overheated and burn out. This condition determines the end point for water circulation.

In order to increase the allowable rate of steam generation beyond the end point just described, it is necessary to increase the size of the path for the downward flow of water. In modern naval boilers, this is accomplished by installing large tubes (3 or more inches in diameter) between the steam drum and the water drums. These tubes, called DOWNCOMERS, are located outside of the furnace and away from the heat of combustion. When a sufficient number of downcomers are installed, all small tubes can be generating tubes, carrying water and steam upward, and all downward flow of water can be carried by the downcomers. The size and number of downcomers installed varies from one type of boiler to another, but some are installed in all modern naval boilers used for propulsion.

In addition to the firing rate (or steaming rate), there are other factors which influence water circulation in boilers. These factors vary with the type of boiler and the conditions of operation; but in general they include the location of the burners, the arrangement of baffles in the tube banks, and the arrangement of tubes in the tube banks.

TYPES OF BOILERS

Boilers may be classified in a number of different ways, according to various design features. Some knowledge of these methods of classification is necessary for an understanding of the design and construction of modern boilers.

First of all, boilers are classified according to the relative location of their fire and water spaces. By this classification, all boilers can be classed as either FIRE-TUBE or WATER-TUBE boilers. In fire-tube boilers the gases of combustion flow through the tubes and thereby heat the surrounding water.

In water-tube boilers, on the other hand, the water flows through the tubes and is heated by the gases of combustion which fill the furnace. All modern naval propulsion boilers are water-tube boilers. Fire-tube boilers are used for propulsion on some merchant ships, but in the Navy they are used only for auxiliary services. (Auxiliary boilers will be described briefly later in this chapter.)

Water-tube boilers are further classified according to the size of the tubes (disregarding the size of downcomers). Boilers having tubes 2 inches or more in diameter are called LARGE-TUBE BOILERS. Boilers having tubes less than 2 inches in diameter are called SMALL-TUBE OR EXPRESS-TYPE BOILERS. Practically all modern propulsion boilers are of the express type.

Water-tube boilers are also classified according to the type of circulation. NATURAL CIRCULATION is of two types, FREE and ACCELERATED. In free circulation boilers, the tubes which connect the lower and upper headers are only slightly inclined. In accelerated circulation boilers, the tubes are installed at a greater angle of inclination; and downcomers are installed to provide a positive supply of relatively cool and dense water to the lower drum or drums. (Natural circulation, whether free or accelerated, depends upon the difference in density between an ascending mixture of hot water and steam and a descending body of relatively cool and steam-free water.) The principle of FORCED CIRCULATION is now being used in some stationary steam plants and in some merchant vessel propulsion boilers. In forced circulation boilers, pumps are used to step up water circulation and thereby increase the capacity. Until recently, all naval propulsion boilers were of the accelerated natural circulation type. However, forced circulation boilers are now being installed on some naval vessels. (Forced circulation boilers will be described later in this chapter.)

With few exceptions, naval propulsion boilers are equipped with superheaters. There are two basic types of modern naval superheater installations: (1) controlled; and (2) un-

controlled. In a boiler with CONTROLLED superheat, the degree of superheat can be changed by regulating the intensity of heat passing through the superheater tube bank, without substantially changing the intensity of heat passing through the generating tube bank. This control is possible because the boiler has two furnaces, one for the saturated side and one for the superheat side. A boiler with UNCONTROLLED superheat, on the other hand, has only one furnace; and since the same furnace gases must be used for heating both the generating tubes and the superheater tubes, the degree of superheat cannot be controlled.

The superheater on a controlled superheat boiler is called an INTEGRAL, SEPARATELY FIRED SUPERHEATER; the other type, where the superheat is not controlled, is known as an INTEGRAL, NOT SEPARATELY FIRED SUPERHEATER. The term INTEGRAL is used here to indicate that the superheater is installed as a part of the boiler itself. (Practically all modern superheaters are integral with the boilers. In some older type ships, however, separate superheat boiler units were provided for superheating the steam from a number of saturated steam boilers.)

Some controlled superheat boilers have RADIANT-TYPE superheaters—that is, the superheater tubes are exposed to the radiant heat of the furnace. More commonly, however, the superheater tubes are protected from radiant heat by water screen tubes. The water screen tubes absorb the intense radiant heat of the furnace, and the superheater tubes are heated by convection currents passing out of the furnace. This type of INTERDECK OR WATER SCREENED superheater is often referred to as a CONVECTION-TYPE superheater. Superheaters on uncontrolled superheat boilers are always heated by convection rather than by radiation. Superheaters on controlled superheat boilers may be heated by radiation, by convection, or by a combination of radiation and convection.

Boilers may also be classified as HEADER TYPE OR DRUM TYPE, depending upon the arrangement of the steam and water spaces. Drum-type boilers are further classified according

to the shape formed by their water tubes. For example, **M-TYPE** and **D-TYPE** boilers are so called because the arrangement of water tubes forms a rough letter **M** or letter **D**.

In the following sections we will take up **M-TYPE**, **D-TYPE**, and **HEADER-TYPE** boilers, since these are now the most widely used naval propulsion boilers.

M-Type Express Boilers

The **M**-type, two-furnace, single-uptake boiler is the kind you are most likely to find on modern combatant vessels. The **M**-type boiler is shown in general outline in figure 2–3, and in detail in the cutaway view of figure 2–4.

Full control of superheat temperature is possible in the **M**-type boiler, due to the fact that each furnace may be separately fired. One advantage of controlled superheat is that designated temperature can be maintained at all speeds,

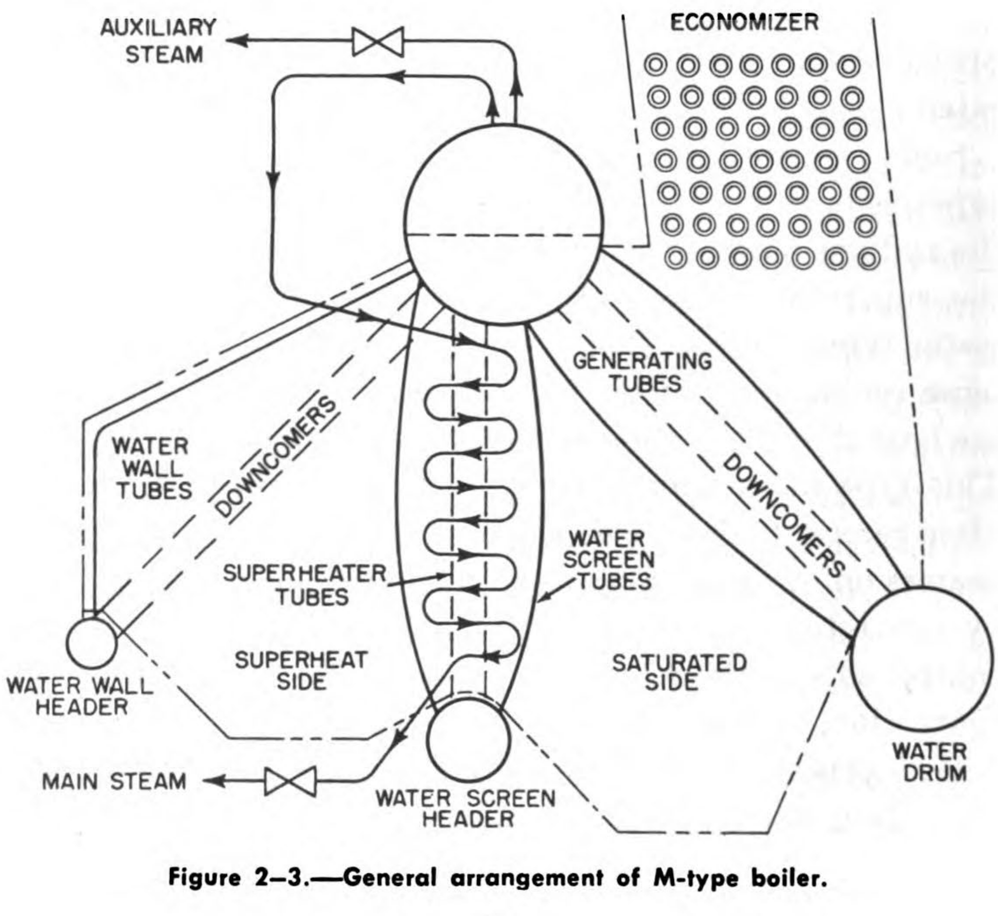


Figure 2–3.—General arrangement of M-type boiler.

regardless of the volume of steam being generated. (When superheat is uncontrolled, designed temperature is normally reached only at full power.) Furthermore, boilers with superheat control can be designed for higher operating temperatures than boilers without superheat control, given the same quality of materials for piping and turbines. When superheat is not controlled, an allowance must be made for the MAXIMUM temperature which might occur under adverse operating conditions.

In the **M**-type boiler, most of the steam is generated in the large bank of tubes on the uptake (economizer) side, although the water wall tubes and water screen tubes are also generating tubes. The **U**-shaped superheater tubes are installed horizontally, and are surrounded and protected by the vertical water screen tubes. The water screen tubes and

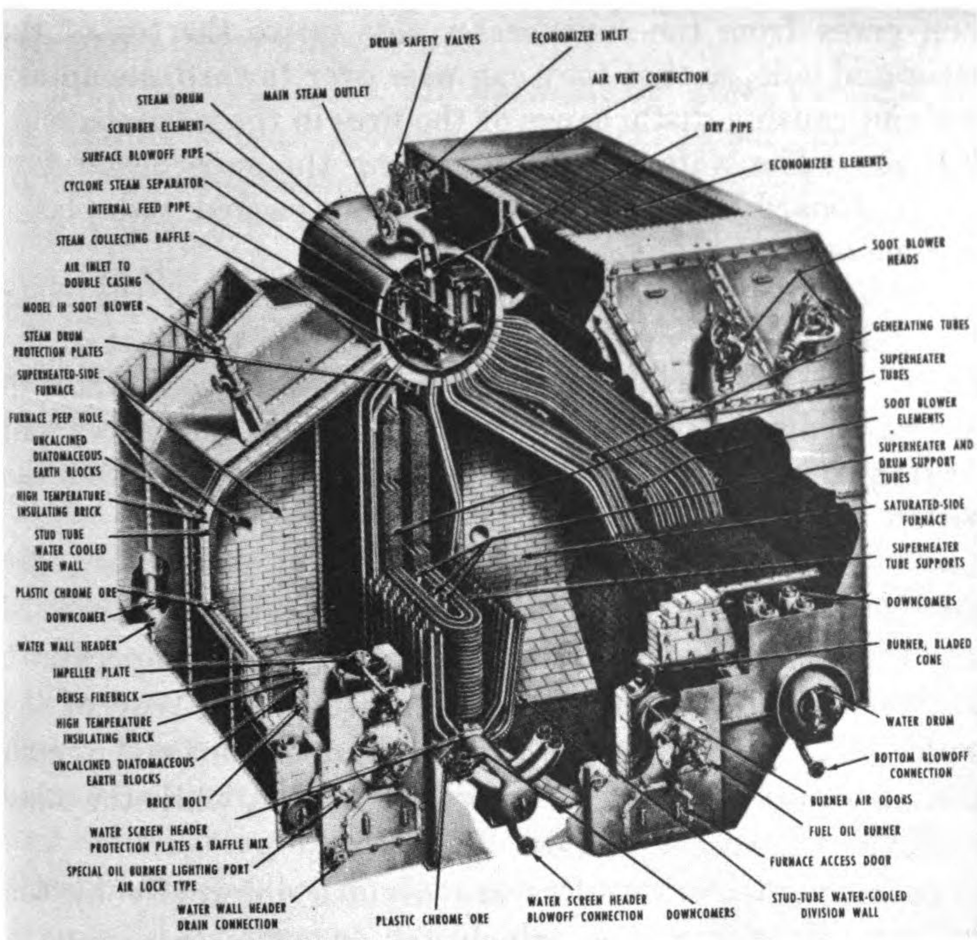


Figure 2–4.—Cutaway view of M-type boiler.

the superheater tubes are installed directly under the steam drum, and together they form the division between the saturated-side furnace and the superheater-side furnace.

The flow of combustion gases within the boiler is partly controlled by gas baffles. The lower half of the row of water screen tubes next to the saturated-side furnace, and the upper and lower ends of the third row of water screen tubes from the superheater-side furnace, are studded and packed with plastic chrome ore. The baffles thus formed on the superheater side direct the combustion gases from the superheater furnace toward the superheater tube nest, and also deflect the gases away from the steam drum and water screen header. The baffle on the saturated side prevents combustion gases from flowing into the superheater tubes, and thus protects the superheater when the superheater side is not in use. In addition, the baffle on the saturated side deflects combustion gases from the superheater side up to the top of the saturated side, so that they can pass over toward the uptake without causing disturbance of the fires in the saturated-side furnace. The water wall tubes along the superheater furnace outboard wall are also studded and packed with plastic chrome ore.

Large-tube downcomers are installed between the inner and outer casings of the boiler, away from the heat of the furnaces. The downcomers carry relatively cool water to the water drum, the water screen header, and the water wall header, thus ensuring adequate water circulation within the boiler.

In the M-type boiler shown in figure 2–4, you can see that the horizontally installed superheater tubes project forward into the boiler furnace. These tubes connect the superheater headers, which are installed vertically at the rear of the boiler. There are generally two headers, and one end of each U-shaped superheater tube enters one header, while the other end enters the other header.

The superheater headers are divided internally by one or more division plates, which act as baffles to direct the flow of steam. Sometimes the sections are separated ex-

ternally, as well as internally, so that there are more than two headers. Part (B) of figure 2–5, for example, shows a superheater in which four headers are arranged so that the steam makes three separate passes through the furnace. The arrows indicate the manner in which the steam passes back and forth between the headers. In each case, of course, it passes from one header to another by way of the U-shaped superheater tubes which connect the headers, as shown in part (A) of figure 2–5. Part (C) shows both headers and tubes, and illustrates the flow of steam through a four-pass superheater. In this arrangement there are two headers; one of them has one internal division plate, and the other has two.

As you can see, the number of passes made by the steam is determined by the number of headers (or header sections). Three-pass and four-pass superseaters are common, but other types are also used.

In an M-type boiler, all MAIN steam flows through the superheater tubes. However, the steam is not superheated unless the superheater-side furnace is lit off—thus the M-type boiler can supply either saturated or superheated steam to the main engines, as desired. For this reason, and because the degree of superheat can be controlled by controlling the intensity of heat in the superheater-side furnace, the boiler is known as a CONTROLLED SUPERHEAT BOILER.

Desuperheaters, which are used on uncontrolled superheat boilers to lower the temperature of AUXILIARY steam, are not required on controlled superheat boilers. Auxiliary steam is drawn directly from the steam drum, and does not pass through the superheater at all.

The economizer on an M-type boiler is located in the uptake space, above the bank of generating tubes. All uptake gases from both furnaces must pass through the economizer unit before going up the stack. The feed water, which flows through the economizer tubes on its way to the steam drum, is warmed by the hot gases; and much of the heat which would otherwise be lost is saved by this method. In general,

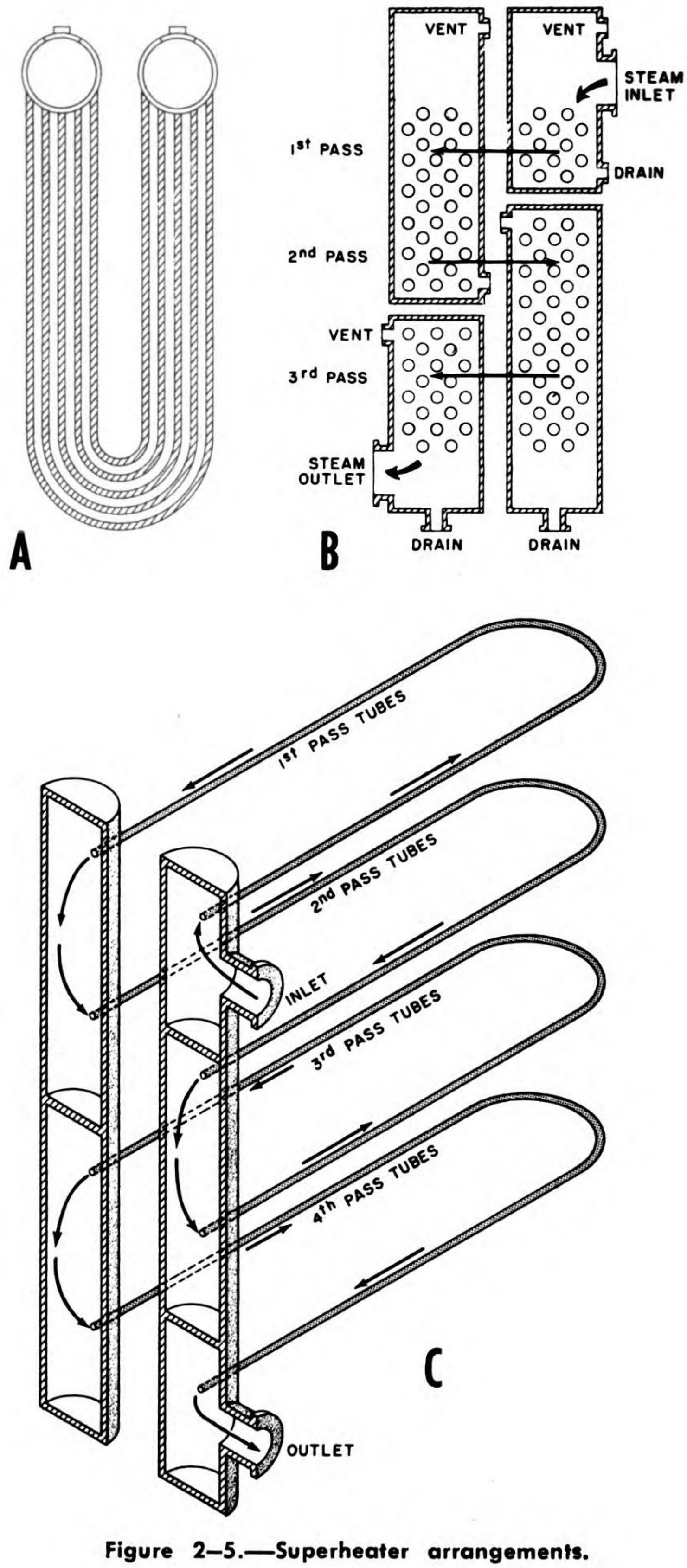


Figure 2-5.—Superheater arrangements.

modern boilers tend to have larger economizer surfaces and somewhat smaller generating surfaces than older types of boilers.

D-Type Express Boilers

The D-type express boiler, sometimes called the two-drum boiler, has one water drum and a side wall header. The water drum is located at the bottom of the boiler, directly under the steam drum. The side wall, back wall, and floor of the furnace are water-cooled. The wall tubes, both side and back, are exposed to the radiant heat of the furnace; the floor tubes provide relatively cool water for circulation.

The integral, interdeck superheater has horizontally-installed U-shaped tubes which project forward into the furnace, between the tubes of the generating bank. As you can see from figure 2–6, this boiler has only one furnace; it is

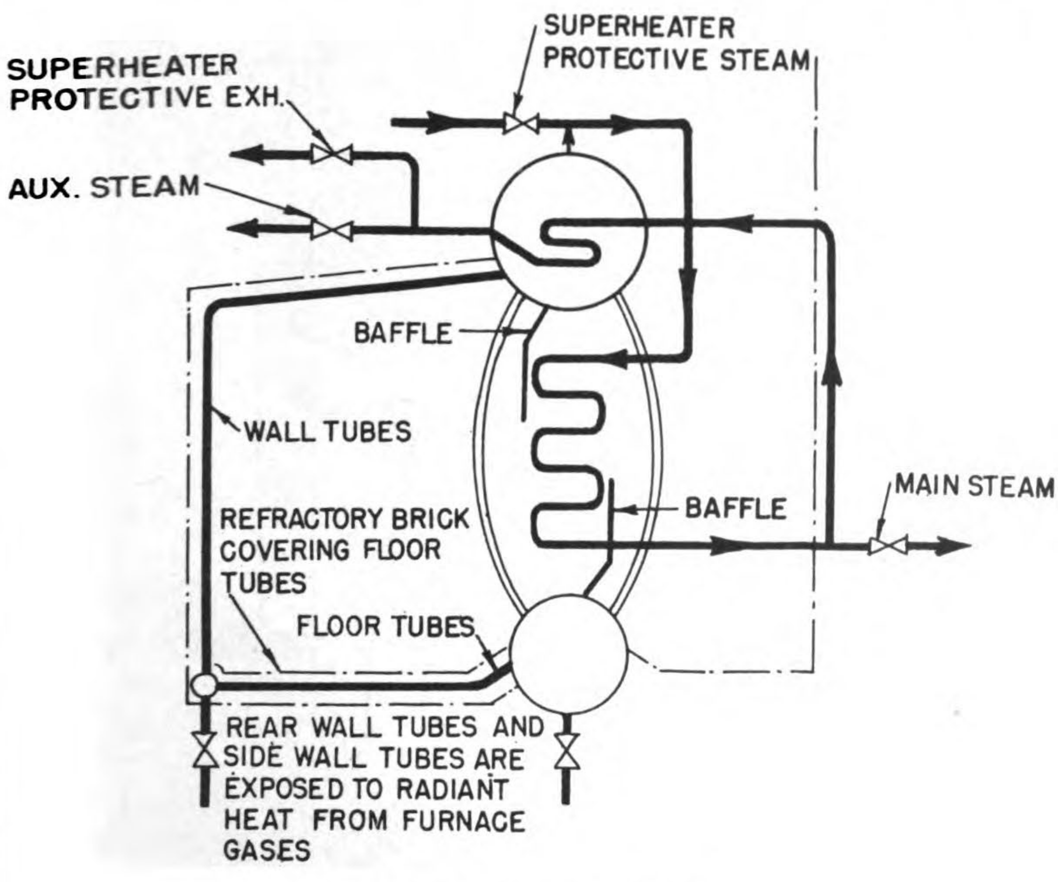


Figure 2–6.—D-type boiler.

therefore classified as an uncontrolled or no control superheat boiler, since superheater tubes and generating tubes cannot be heated independently of each other.

The regular D-type boiler was developed for use in merchant vessels. Although some of these D-type boilers are used in Navy transports and other auxiliary vessels, they are not otherwise in common use in the Navy. However, a modification of the D-type boiler is now standard for destroyer escort vessels, and has become known as the destroyer escort or DE boiler. This type of boiler is shown in general arrangement in figure 2–7, and in cutaway view in figure 2–8. The destroyer escort boiler, like the regular D-type, is a single-furnace uncontrolled superheat boiler. In the de-

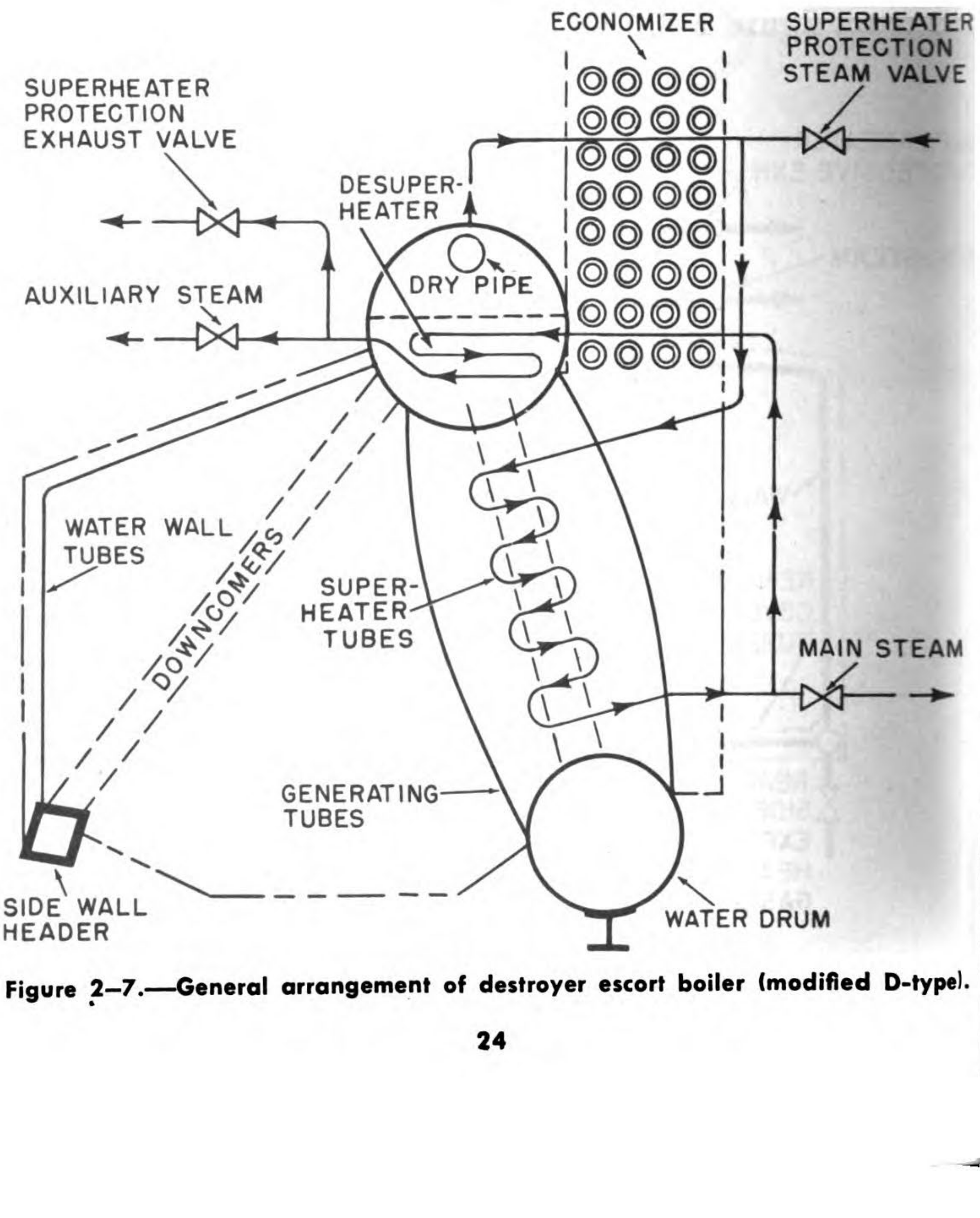


Figure 2–7.—General arrangement of destroyer escort boiler (modified D-type).

stroyer escort boiler, the water drum is not directly under the steam drum, but is slightly to one side; thus the bank of generating tubes is inclined at a slight angle, rather than being straight up and down. Instead of floor tubes, the DE boiler has downcomers to provide cool water for circulation.

In order to understand the design of the DE boiler, look at figure 2–7 and trace the flow of steam. First of all, you must remember that this is a single-furnace uncontrolled superheat boiler—that is, when fires are lit in the furnace, both the generating tubes and the superheater tubes will be heated. In order to protect the superheater tubes from

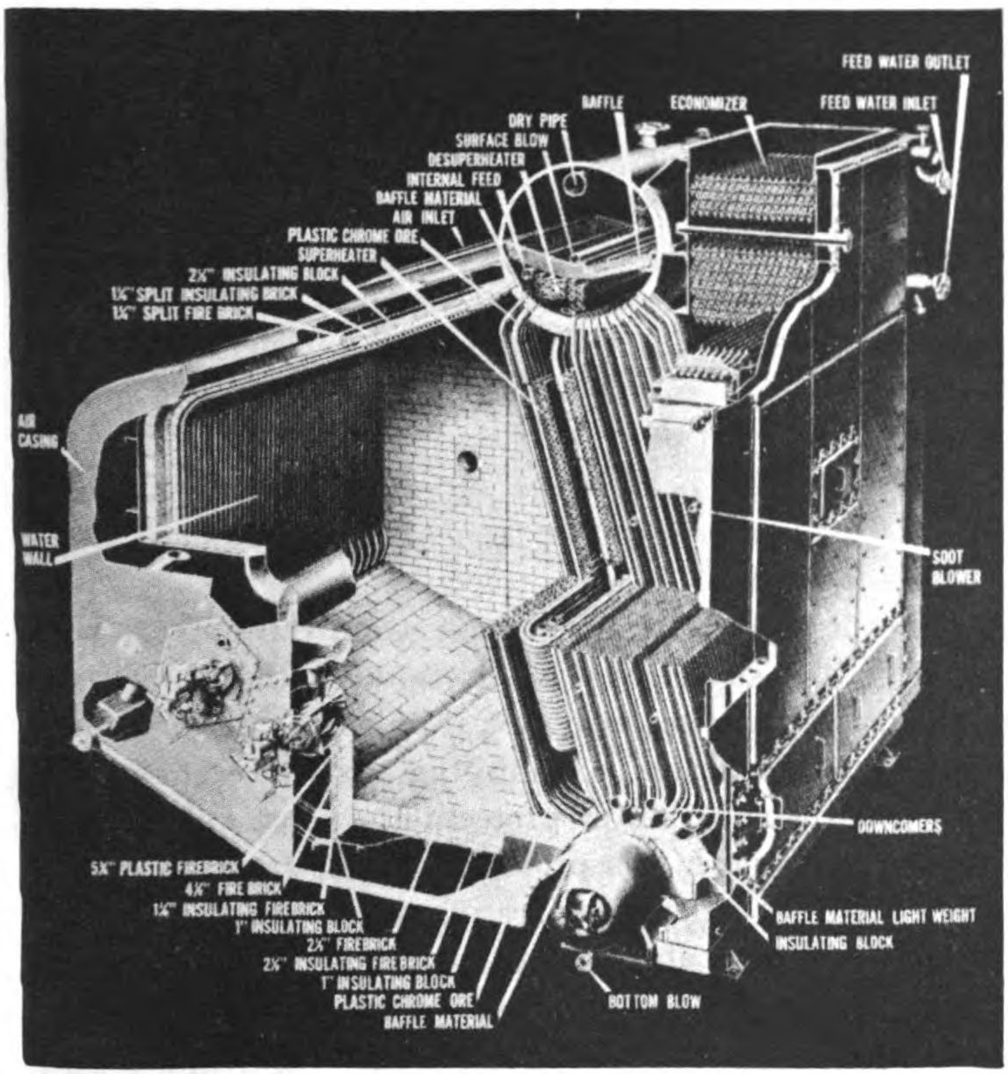


Figure 2–8.—Cutaway view of destroyer escort boiler (modified D-type).

serious heat damage, ALL steam generated in the steam drum must be led through the superheater. The saturated steam is led from the dry pipe to the superheater inlet, through the superheater tubes, and then to the main steam line by way of the superheater outlet. (Thus ALL steam supplied to the main engines is superheated.)

Auxiliary steam must also go through the superheater, as described above. However, since auxiliaries are designed to operate on saturated or only slightly superheated steam, the superheat must be removed from the steam which is to be used for auxiliary purposes. The steam goes through the desuperheater, a coil of piping which is submerged in the water of the steam drum, and there gives up its superheat. The steam which passes out of the desuperheater and into the auxiliary line is once again at (or very close to) saturation temperature.

So far, we have considered the flow of steam as it occurs AFTER the boiler has been cut in on the steam line. But what happens when a cold boiler is lit off? How can the superheater tubes be protected from the heat of the furnace, AFTER the fires are lighted but BEFORE sufficient steam has been generated to ensure a flow through the superheater? During this period of time immediately after lighting off, it is necessary to protect the superheater by bringing in steam from another boiler or from some other source (Navy yard, tender, etc.) This protective steam is drawn in through the superheater protection steam valve; from there it goes to the superheater inlet, through the superheater tubes, out the superheater outlet, through the desuperheater coil in the steam drum, and into the auxiliary exhaust line by way of the superheater protection exhaust valve. It is necessary to furnish this protective steam from an outside source until the boiler is generating steam and the pressure has been built up to about 100 psi.

The economizer unit on a destroyer escort boiler is practically the same as that on the M-type boiler, previously described.

Header-Type Boilers

Header-type boilers such as the one shown in figure 2–9 are installed on many auxiliary vessels and on some escort carriers (CVE's). In this type of boiler the main water spaces consist of front and rear sections (headers) which are connected by water tubes. The steam drum is located above the front header section; it is connected to both header sections by water tubes. The generating tubes slope upward toward the rear of the furnace, so that the heated water and steam can rise and so maintain circulation within the boiler. (Downcomers are also installed to aid circulation.)

The header-type boiler has an economizer and an integral, interdeck superheater. As you can see from the picture of this boiler, there is only one furnace; so the superheat is uncontrolled. A desuperheater is installed in the steam drum to lower the temperature of the steam used for auxiliary purposes.

BOILER CONSTRUCTION

It is important to have some knowledge of the details of boiler construction, in order to understand why and how a boiler operates. In the following sections we will take up construction details of the principal parts of modern express boilers. Although emphasis is placed primarily on drum-type boilers, the construction of header-type boilers may be assumed to be very similar.

Drums and Headers

The STEAM DRUM is always located at the top of the boiler. It is cylindrical in shape, and (except in some header-type boilers) it runs from the front of the boiler to the back. The steam drum provides a space for the accumulation of steam generated in the tubes and for the separation of moisture from the steam; and it serves as a storage space for boiler water, which is distributed from the steam drum to the generating and downcomer tubes. (In normal operation, the steam drum is kept about half full of water.) In addition

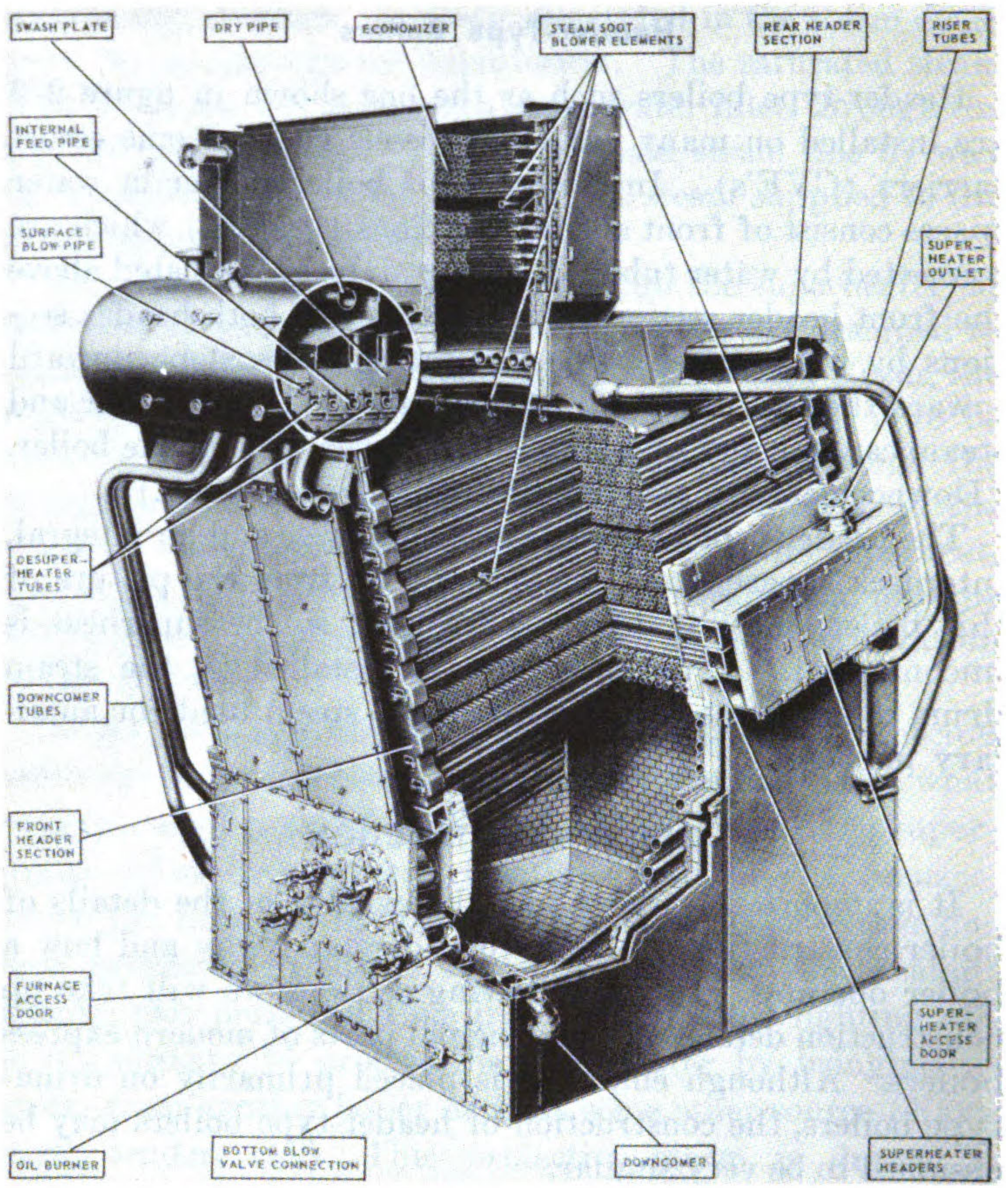


Figure 2–9.—Small-tube, straight-tube, single-pass, sectional header boiler.

to these basic functions, the steam drum either contains or is connected to many of the important controls and fittings required for the operation of the boiler.

The WATER DRUMS equalize the distribution of water to the generating tubes, and provide a place for the collection of loose scale and other solid matter in the water. This sediment is removed from the water drums by periodic operation of the bottom-blow valves. Water drums are sometimes called MUD DRUMS, because the solid matter which

settles in them usually forms a thick sludge or mud. Water drums are cylindrical in shape. They are considerably smaller than the steam drum.

Most modern naval boilers have one water drum and one or two HEADERS which serve the same purpose as water drums. The distinction between a header and a water drum is merely one of size: Drums are large enough for a man to enter, but headers are too small to be entered. Headers on M-type boilers are circular or oval in cross-section; the water wall header on DE boilers is usually square in cross-section.

The materials used and the manner of construction are essentially the same for steam drums, water drums, and headers. In modern boilers designed for operating pressures above 300 psi, the drums and headers are made of carbon-molybdenum steel.

Each drum is made of two sheets of steel, which are rolled to semi-cylindrical shape. The sheet in which the tube holes will later be drilled is called the TUBE SHEET; the other is called the WRAPPER SHEET. The drum heads are

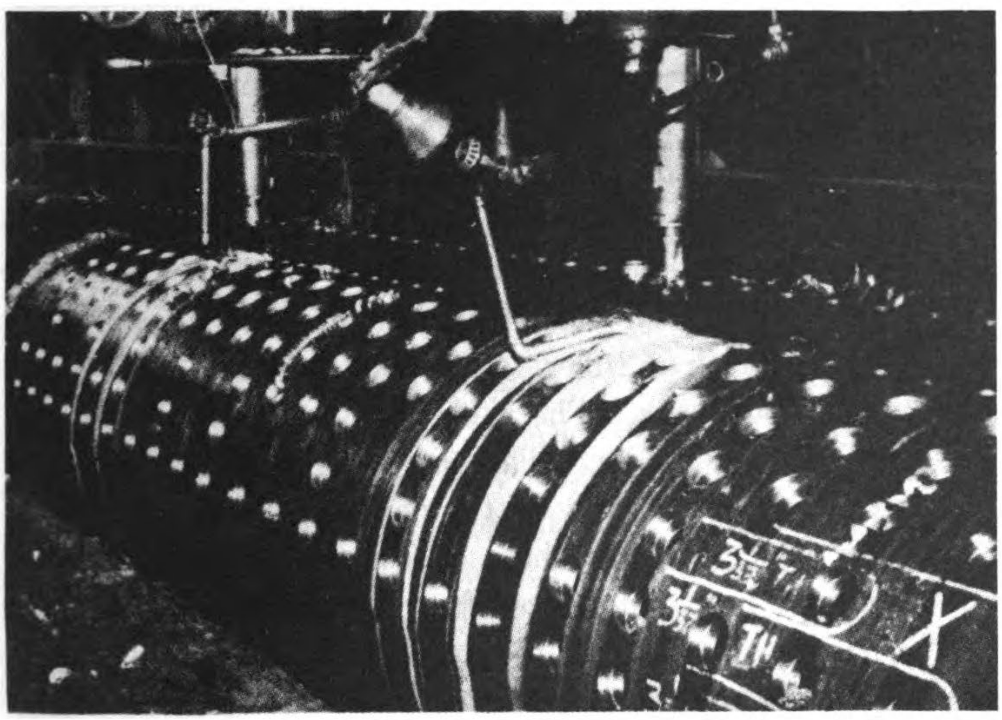


Figure 2–10.—Drilling tube holes in boiler drum.

shaped by forging. The tube sheet, wrapper sheet, and drum heads are joined by electric welding. The drum is then heat-treated and tested, and the required holes are drilled in the tube sheet. Figure 2–10 shows tube holes being drilled in a boiler drum.

Drum heads are made with a central manhole, through which men may enter the drum to inspect, clean, and repair the drum, the internal fittings, and the tubes. Additional openings in the front heads of steam drums allow for the connection of various fittings. Handholes are provided throughout the length of headers, so that tubes will be accessible for inspection, cleaning, and repair.

Generating and Circulating Tubes

Most of the tubes contained in a modern boiler are generating or circulating tubes. They are usually 1 inch in outside diameter (1″ OD), but slightly larger tubes are often used for water screens, water walls, and for the two rows of tubes nearest the furnace. Tubes are made of steel which can withstand high pressures and high temperatures; it is similar to the steel used for steam and water drums. Almost all modern boiler tubes are seamless. They are made by the cold-drawing process, and are cold-bent to the required shape.

If you look back at the cutaway view of an M-type boiler (fig. 2–4), you will see that the bank of generating tubes consists of a great many individual tubes which are installed more or less vertically. Identification of tubes is made by LETTERING the rows of tubes, and NUMBERING the individual tubes within each row. The tube rows run from the front of the boiler to the rear. The row nearest the furnace is row A, the next row is row B, the next is row C, and so on, in regular sequence. If there are more than twenty-six rows in a tube bank, the rows after row Z are lettered AA, BB, CC, and so on. Each tube in each row is then designated by number, beginning with 1 at the front of the boiler and numbering back toward the rear. Thus the designation of

"tube number E–7, right" tells you that the tube is the seventh tube from the front, in the fifth row away from the furnace, in the right-hand tube bank as you face the front of the boiler.

In modern naval express boilers, the tubes usually enter the steam and water drums at right angles to the drum surfaces (tube sheets). Therefore, the curvature of all tubes in any one row will be the same, but the particular shape will be different for each row of tubes. This method of tube installation allows the maximum number of tube holes to be drilled in the steam and water drums, with a minimum weakening of the drums. (Other methods of tube installation, such as making all tubes straight, or making all tubes curved to an arc of a circle, have some advantages for ships in which space and weight limitations are not as important as they are in naval vessels.)

Downcomer tubes are made of seamless drawn steel tubing. They vary in size from 3 to 7 inches, outside diameter, depending upon the circulation requirements of the boiler. In general, the combined capacity of all downcomers is likely to be several times the capacity of the generating tubes. Downcomers connect the steam drum with the water drums and headers. They are almost always installed outside of the inner casing. In air-encased boilers (that is, boilers with double casings) the downcomers are installed between the inner and the outer casings.

Superheaters

Superheater headers and tubes are made of chrome-molybdenum steel, so that they can withstand the extremely high temperatures to which they are subjected. Most superheater installations at the present time cannot withstand temperatures above 1150° F; but the development of improved alloy steels will undoubtedly make higher temperatures possible in the future.

Superheater headers are constructed in very much the same way as steam and water drums, except that some super-

heater headers have nearly flat tube sheets welded to circular wrapper sheets. Superheater tubes are usually straight (unlike generating and circulating tubes), except for the **U**-shaped bend; therefore, they do not enter circular or oval-shaped headers at right angles to the header surface. Superheater headers are usually installed vertically or at a slight angle at the rear of the boiler, so that the horizontal **U**-shaped tubes project forward into the furnace. In some designs, however, the superheater tubes are installed vertically and the headers are installed horizontally, parallel to the steam drum.

Desuperheaters

In boilers with uncontrolled superheat, it is necessary to lead ALL steam through the superheater in order to protect the superheater tubes from heat damage. The steam which is to be used for auxiliary purposes must then be led through the desuperheater, where it is cooled down nearly to saturation temperature again before it enters the auxiliary steam line.

A desuperheater consists essentially of an **S**-shaped tube or coil of piping installed in the water space of the steam drum.

Figure 2–11 gives a phantom view of a steam drum with the desuperheater installed. The desuperheater shown in this illustration is made by forging adjacent tube ends into

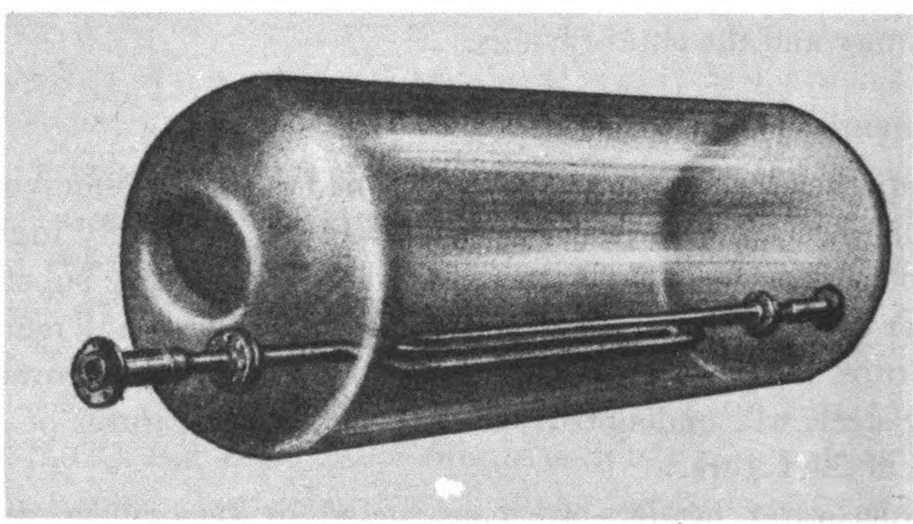


Figure 2–11.—Phantom view of steam drum, showing desuperheater.

return bends. Most commonly, however, the desuperheater is made up from straight and **U**-bend pipe sections, which are brought in through the manhole in the drum head and are bolted together inside the steam drum.

Economizers

All feed water flows through the economizer tubes just before entering the boiler. The economizer is located in the uptake space, where it receives heat from the rising gases of combustion.

M-type boilers have about sixty 2″ OD economizer tubes. The tubes may be straight, **S**-shaped (continuous loop), bifurcated, or **U**-shaped. Most naval boilers have **U**-shaped economizer tubes, similar to the one shown in figure 2–12.

In almost all economizers the tubes have some sort of metal projections from the outer tube surface, to increase the heat-transfer surface. In many designs these metal projections are in the form of radial fins or gill rings, such as those shown on the tube in figure 2–12; however, other types of projections are also used.

There are three kinds of headers on an economizer: (1) the INLET HEADER, which receives and distributes the feed water into the inlet ends of the first row of tubes; (2) the RETURN HEADERS, which connect the outlet ends of one row

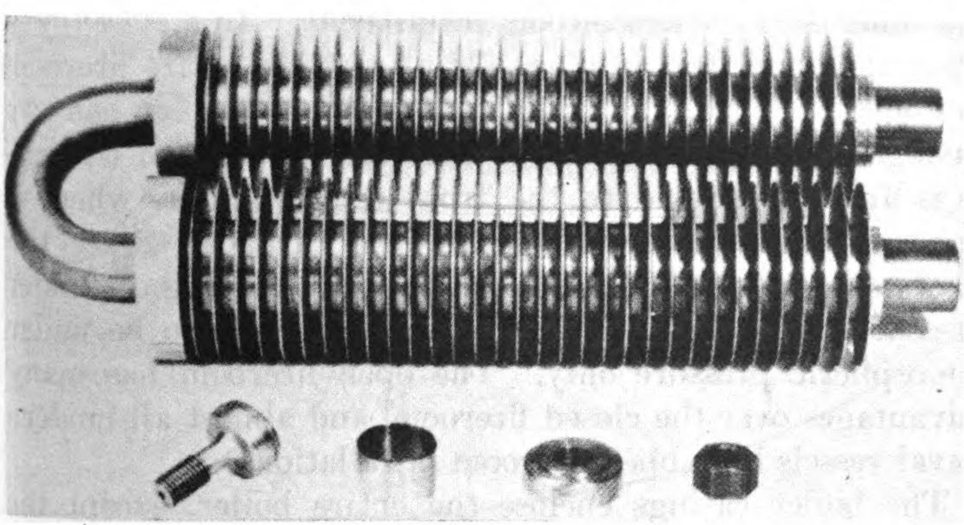


Figure 2–12.—U-bend economizer tube with aluminum gill rings.

of tubes with the inlet ends of the next row; and (3) the OUTLET HEADER, which collects the heated water from the outlet ends of the last row of tubes and leads it into the steam drum by way of the internal feed line. (The internal feed line is classified as an internal fitting and, as such, is discussed in the next chapter.)

Air Heaters (Preheaters)

Although air heaters increase the over-all boiler efficiency by their utilization of heat which would otherwise be wasted, their space and weight requirements make them unsuitable for use in propulsion boilers on naval combatant ships. However, you should be familiar with their purpose and design, since they are still installed on some auxiliary vessels.

An air heater (or a preheater, as it is sometimes called) consists of an arrangement of tubes located in the uptake. The air for combustion flows through the tubes and is preheated by combustion gases on their way up the stack. In general principle, it is very similar to the economizer, in which feed water is heated by waste gases of combustion. Air heater tubes are of fairly light construction, however, since operating air pressures are low.

Casings

Boilers are enclosed by either one or two casings, depending upon the type of fireroom installation. In a closed fireroom the boiler has only one casing and the entire fireroom is under pressure. In an open fireroom the boiler has two casings. Air for combustion is forced in between the casings and led around to the front of the boiler, where it flows through the registers into the furnace. Since the combustion air can be forced in between the casings under pressure, it is possible for the fireroom itself to be under atmospheric pressure only. The open fireroom has many advantages over the closed fireroom, and almost all modern naval vessels have open fireroom installations.

The boiler casings enclose the entire boiler, except the steam drum, up to the uptakes. The uptakes join the boiler

to the smokepipe and are, in effect, a continuation of the casing.

Both inner and outer casings of boilers on combatant ships are constructed of reinforced spot-welded steel panels. The panels are flanged and bolted together, and the joints are made airtight by means of asbestos gaskets. The casings are made in small sections so that they may be removed for inspection and repair of boiler parts.

Saddles and Supports

Each water drum and water header rests upon two saddles, one at the front of the drum and one at the rear. The

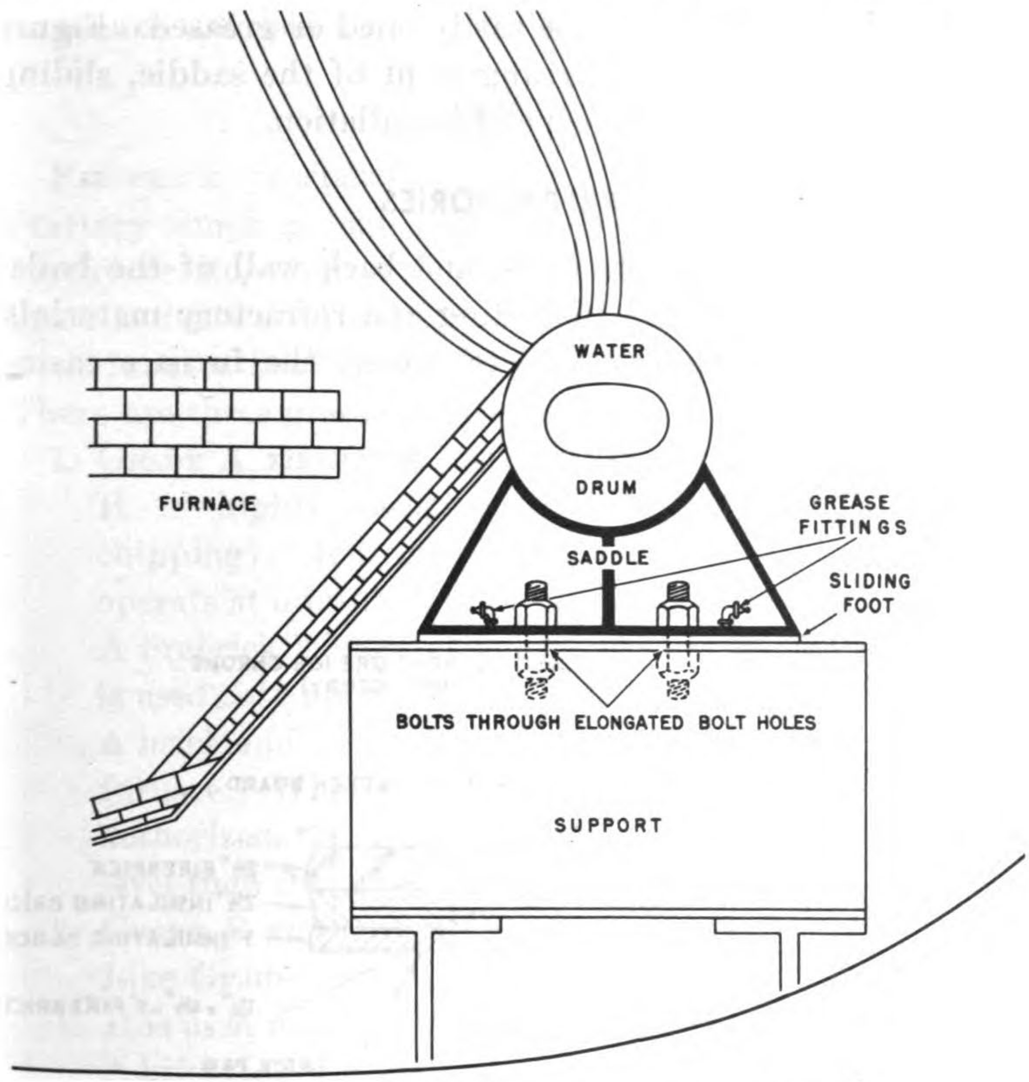


Figure 2–13.—Boiler saddle and support (front view).

upper flanges of the saddles are curved to fit the curvature of the drum, and are welded to the drum. The bottom flanges are flat, and rest on huge beams built up from the ship's structure. The bottom flange of one saddle is bolted rigidly to its support. The bottom flange of the other saddle is also bolted to its support, but the bolt holes are elongated in a fore-and-aft direction; as the drum expands or contracts because of temperature changes, the saddle which is not rigidly fastened to the support accommodates to the changing length of the drum by sliding backward or forward over the support. The flanges which are not rigidly fastened are known as BOILER SLIDING FEET. The sliding feet of most modern boilers are provided with fittings so that they may be easily oiled or greased. Figure 2–13 shows the general arrangement of the saddle, sliding feet, and support on one type of installation.

REFRACTORIES

The floor, front, side walls, and back wall of the boiler furnace are lined with insulating and refractory materials. The refractory lining serves to protect the furnace casing

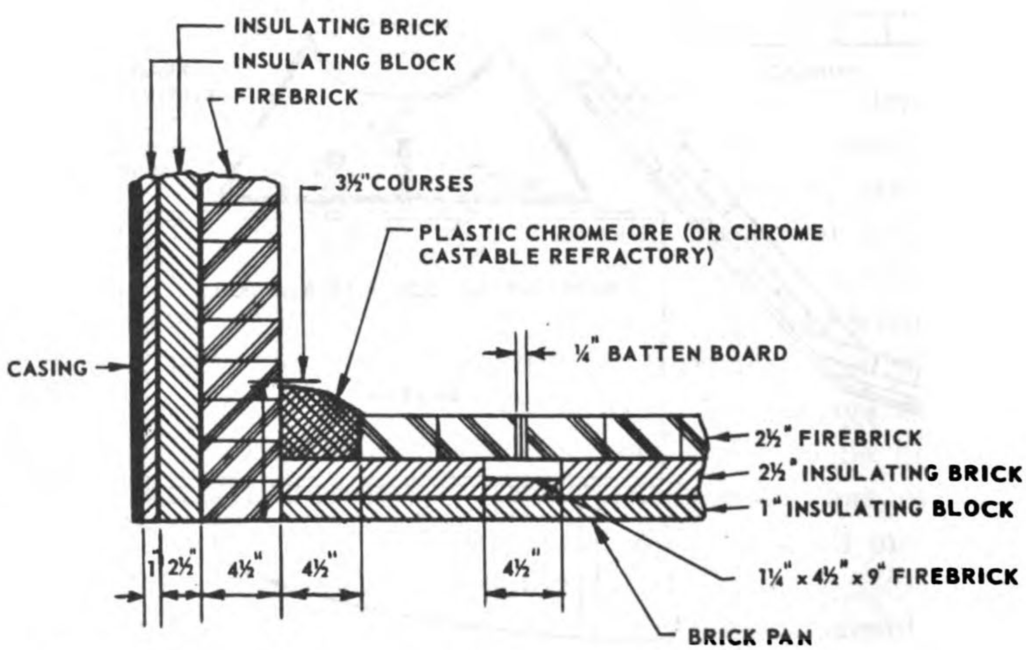


Figure 2–14.—Refractory installation at junction of vertical wall and floor.

and to prevent loss of heat from the furnace. Refractories retain heat for a relatively long period of time, and so help to maintain the high furnace temperatures which are necessary for complete and efficient combustion of fuel. Refractories are also used to form baffles which direct the flow of combustion gases and protect drums, headers, and tubes from flame and excessive heat.

There are many different kinds of refractory materials. The particular use of each type is determined by the chemical and physical characteristics of the refractory material, in relation to the required conditions of service. Figure 2–14 shows the position in which different types of refractories are installed.

Firebrick

FIREBRICK, or FIRECLAY BRICK, is a high-temperature refractory which is made either principally or entirely of the earthy or stony mineral aggregate called FIRECLAY. Firebrick is dense and tough, and can be used in direct contact with furnace flame. It is resistant to attack by acid slag. There are three grades of firebrick:

1. GRADE A FIREBRICK has a softening point of 3245° F. It is highly resistant to spalling (crumbling or chipping). It is used in the furnaces of boilers which operate at unusually high furnace temperatures. Grade A firebrick is more expensive than Grade B brick, and is used only upon authorization from BuShips. Grade A brick and Grade B brick are seldom used in the same furnace. Where their use in the same furnace is authorized, the Grade B brick is always used at a lower level than the Grade A.
2. GRADE B FIREBRICK has a softening point of 3170° F. Like Grade A brick, it is highly resistant to spalling. It is used in the same positions in the furnace as Grade A brick, but it is used when operating conditions are not severe enough to warrant the use of Grade A firebrick.

3. GRADE C FIREBRICK is a high-heat brick suitable for use in shore installations only. It has a softening point of 3092° F. It is much less resistant to spalling than either Grade A or Grade B brick.

High-Temperature Insulating Brick

High-temperature insulating bricks are soft and light in weight. They are used to back up firebrick, and must never be used in direct contact with flame. Insulating bricks possess insulating properties and resistance to temperatures up to 2500° F. There are two types of insulating brick; one is composed mostly of fireclay, and the other is composed of diatomaceous earth (a porous, earthy material which is similar in physical properties to chalk or clay).

Insulating Block

Insulating block is composed of uncalcined diatomaceous earth, mixed with asbestos fiber. It is never used in direct contact with flame, nor in any place where the temperature will exceed 1500° F.

Plastic Firebrick

Plastic firebrick, or FIRECLAY REFRACTORY PLASTIC MIX is composed of the same material as firebrick, but the bonding material (clay) is in a raw condition. Plastic firebrick is particularly useful because it can be pounded into spaces which would otherwise require firebrick of special or unusual shape. Plastic firebrick is practically equal to standard firebrick in refractory qualities. However, it is not so strong and not quite so stable in volume, and is therefore not suitable for general use in side or rear walls. Plastic firebrick is an excellent material for repairing brickwork, for topping off side and back walls, and for constructing and repairing burner openings. The strength of plastic firebrick increases with increasing temperature, in the range from 1500° to 3000° F; but it should not be used in parts

of the furnace where it would be exposed to temperatures above 3000° F.

Plastic firebrick is shipped in resealable metal drums. The required amount may be taken out, and the remainder covered with a damp cloth and left in the drum, which is then resealed. If plastic firebrick becomes too dry or too hard in the drum, it can be returned to workable consistency by cutting it up into small pieces, spraying it with clean water, and allowing it to stand for several hours. If plastic firebrick is too soft to work with when it is removed from the container, the proper consistency can be obtained by cutting it into small pieces and allowing it to dry for several hours, without any application of heat.

Baffle Mix

Baffle mix is a mixture of refractory materials and heat-resistant hydraulic cement which acquires its strength without being heated. It is shipped dry, and must be mixed with water for use. Class A baffle mix contains hard, dense grains of refractory material; it will withstand service temperatures up to 2500° F. Class B baffle mix contains crushed insulating brick as the refractory ingredient; it will withstand service temperatures up to 2200° F. As you can see from these temperature limits, baffle mix is not used in the hottest parts of the furnace.

Baffle mix is particularly useful where odd shapes or unusual thicknesses are required, and in places where it would be difficult to install firebrick. It makes a smooth wall, without joints, and offers less resistance than firebrick to the flow of combustion gases. Although baffle mix is not used extensively at the present time, it is likely to be used more and more in the future.

High-Temperature Castable Refractory

High-temperature castable refractory (sometimes called 3000° F CASTABLE REFRACTORY) is another mixture of hard, dense, refractory grains and hydraulic cement which ac-

quires its strength without being heated. Like baffle mix, it is shipped dry and must be mixed with water for use. Unlike baffle mix, however, it may be used instead of plastic firebrick around burner openings and peepholes.

Heat-Setting Mortar

Heat-setting mortar is a finely-ground fireclay material which develops strength only when fired to approximately 2000° F. Heat-setting mortar will not shrink or fuse at temperatures up to 3000° F.

Air-Setting Mortar

Air-setting mortar is a finely-ground fireclay material which develops strength at room temperature and maintains this strength without fusion or shrinkage up to 3000° F. It is used for laying firebrick.

Air-setting mortar is sometimes shipped moist, in metal drums, and sometimes dry. If it is received in the dry form, it should not be used immediately after mixing, but should be allowed to stand for a few hours.

Plastic Chrome Ore (PCO)

Plastic chrome ore (PCO) is a different kind of refractory from those used in the construction of furnace walls. It is composed of ground chrome ore and liquid sodium silicate. Plastic chrome ore is shipped in airtight containers, and is ready for use; it should never be mixed with water, cement, or any other material.

Plastic chrome ore is used as the water wall refractory in naval boilers, as shown in figure 2-15. It is also used to form gas bafflles which control the flow of combustion gases within the boiler. PCO is particularly good for these uses because it possesses the following characteristics:

1. It forms a very strong bond with the steel studs and tubes in the boiler wall.

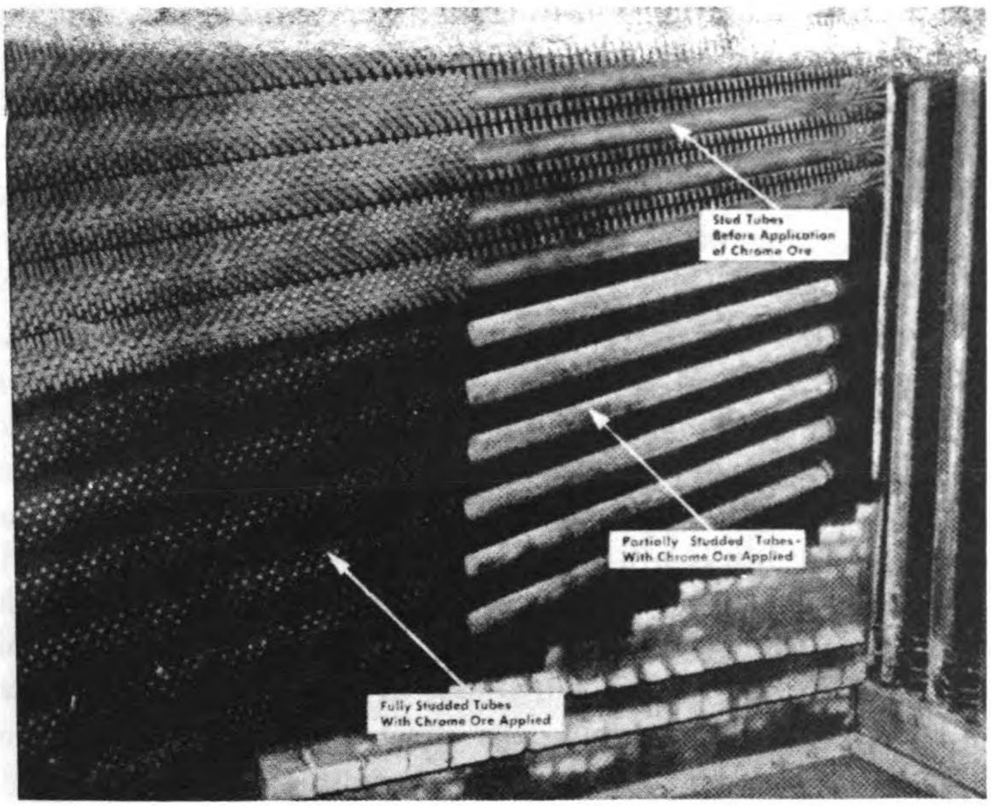


Figure 2–15.—Portion of stud-tube furnace wall (header-type boiler).

2. It can withstand a tremendous drop in temperature from its hot side to its cold side, without shattering. The temperature of the surface exposed to the flame may be about 3000° F.; whereas the temperature at the point of contact with the tubes may be only a few hundred degrees. Thus a half-inch thickness of PCO may be subjected to a temperature drop of 2500° F. It is doubtful that any other type of refractory material would withstand this treatment.
3. It is highly resistant to the action of ash, slag, sulphur, and other combustion products which may be present in the furnace. Because PCO is so resistant to the chemical action of these materials, it is often referred to as a NEUTRAL refractory.

Chrome Castable Refractory

Chrome castable refractory is a mixture of ground chrome ore and hydraulic-setting cement. It is supplied in dry

form, and requires the addition of water. It develops strength within 24 to 48 hours, without being heated. Chrome castable refractory may be used instead of PCO on studded tubes and for fillets or wall copings. It must NEVER be installed around burner openings.

FURNACE CONSTRUCTION

The boiler furnace is essentially a space provided for the mixing of air and fuel and for the combustion of the fuel. For the sake of maximum efficiency, all combustion should take place in the furnace itself, and none in the tube banks; therefore the furnace must be as large as possible, within the overall size limits allowed for the boiler.

The boiler furnace casing is a rectangular steel box which is lined with refractory materials. It is supported by rigid steel beams and angles which are, in turn, supported by the water drums and headers. In effect, therefore, the furnace is suspended from the water drums and headers.

The flat bottom part of the furnace is called the FLOOR. The SIDE WALLS extend from the floor up to the water drums or headers. The BACK WALL and the FRONT WALL extend from the floor up to the steam drum. The front wall is pierced by burner openings and peepholes.

Furnace linings are secured with ANCHOR BOLTS made of heat-resistant nickel-chromium alloy steel. The bolts may be either straight or, more commonly, hooked at the end. Figure 2–16 shows both the straight and the hooked-end anchor bolts.

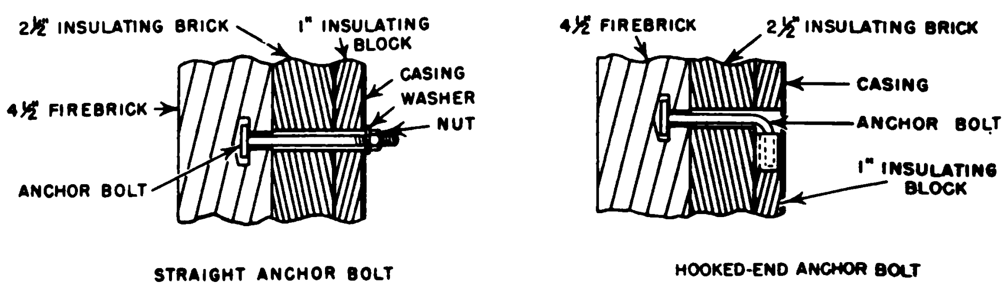


Figure 2–16.—Use of straight and hooked-end anchor bolts in furnace construction.

The refractory lining of the furnace is shown in figures 2–14 and 2–16. As you can see from these illustrations, the first layer inside the steel casing is of insulating block, 1-inch thick; the next layer is of insulating brick, 2½ inches thick; and the innermost layer, which is in contact with combustion gases, is of firebrick, 4½ inches thick on the side walls and 2½ inches thick on the floor.

NEW TYPES OF PROPULSION BOILERS

The propulsion boilers which are now being installed in some ships of the new DL (destroyer leader) class are different in several important respects from other modern naval boilers. The most striking feature of the newer boilers is their high operating pressure—1200 psi or above, as compared with approximately 550 psi for the **M**-type boiler previously described, and 435 for the DE boiler.

The development of these 1200-psi boilers is in line with the general trend toward higher operating pressures and temperatures. High-pressure boilers have the advantage of being smaller, lighter, and more economical of fuel, for any given shaft horsepower, than boilers which operate at lower pressures.

One of the new 1200-psi boilers is essentially a **D**-type boiler which has been modified to withstand the high pressures and temperatures. Others, however, operate on the principle of FORCED CIRCULATION, rather than natural circulation, and are quite different in design from the boilers previously described.

The 1200-psi D-type Boiler

This express-type single-furnace boiler is very similar to the DE boiler shown in figures 2–7 and 2–8. It has an integral superheater which is arranged interdeck between the screen tubes and the main generating tube bank. Since it is an uncontrolled superheat boiler, a desuperheater is installed to remove the superheat from auxiliary steam. Water circulation is provided by downcomers, which run

from the water spaces of the steam drum to the water drum, the side water wall header, and the rear water wall header. The economizer is of the stud-tube, continuous-loop type, and is installed in the uptake above the bank of generating tubes.

The steam drum pressure is 1260 psi and the operating pressure at the superheater outlet is 1200 psi, when the boiler is steaming at full-power capacity. The steam temperature at the superheater outlet is 950° F.

Forced Circulation Propulsion Boilers

In natural circulation boilers, the circulation of water and steam results from the difference in density between an ascending mixture of hot water and steam and a descending body of relatively cool and steam-free water. Forced circulation boilers, as their name implies, do not depend upon this thermal head resulting from density differences; instead, pumps are used to force the water through the various circuits.

Forced circulation boilers have been used for a considerable time in stationary plants, in locomotives, and in some merchant ships; but their use for propulsion of naval vessels is relatively new. Natural circulation boilers have been preferred for naval use because they are simpler in design, less liable to tube failure, and easier to maintain. In addition, natural circulation boilers have, until quite recently, met all of the Navy's requirements as to steam pressures and temperatures. For high-pressure boilers, however, forced circulation has such marked advantages over natural circulation that increasing use will probably be made of forced circulation boilers.

The arrangement of the component parts of a natural circulation boiler is limited by the requirement that hot water and steam must be allowed to flow upward while cooler water flows downward. The arrangement of units in a forced circulation boiler is not so limited, because the circulation is controlled by pumps. Thus a greater flexi-

bility of arrangement is possible, and the boiler may be designed for compactness, savings in weight and space, and maximum heat absorption.

Figure 2–17 shows the general arrangement of the ONCE-THROUGH type of forced circulation boiler. Notice that this boiler has no drum. The water is pumped through one or more circuits, including an economizer section, a generating section, and a superheater section. In the once-through forced circulation boiler, the amount of feed water pumped into the circuits is equal to the amount drawn off in steam. Automatic controls are always used in this type of boiler, in order to ensure sensitive response to fuel and feed water requirements.

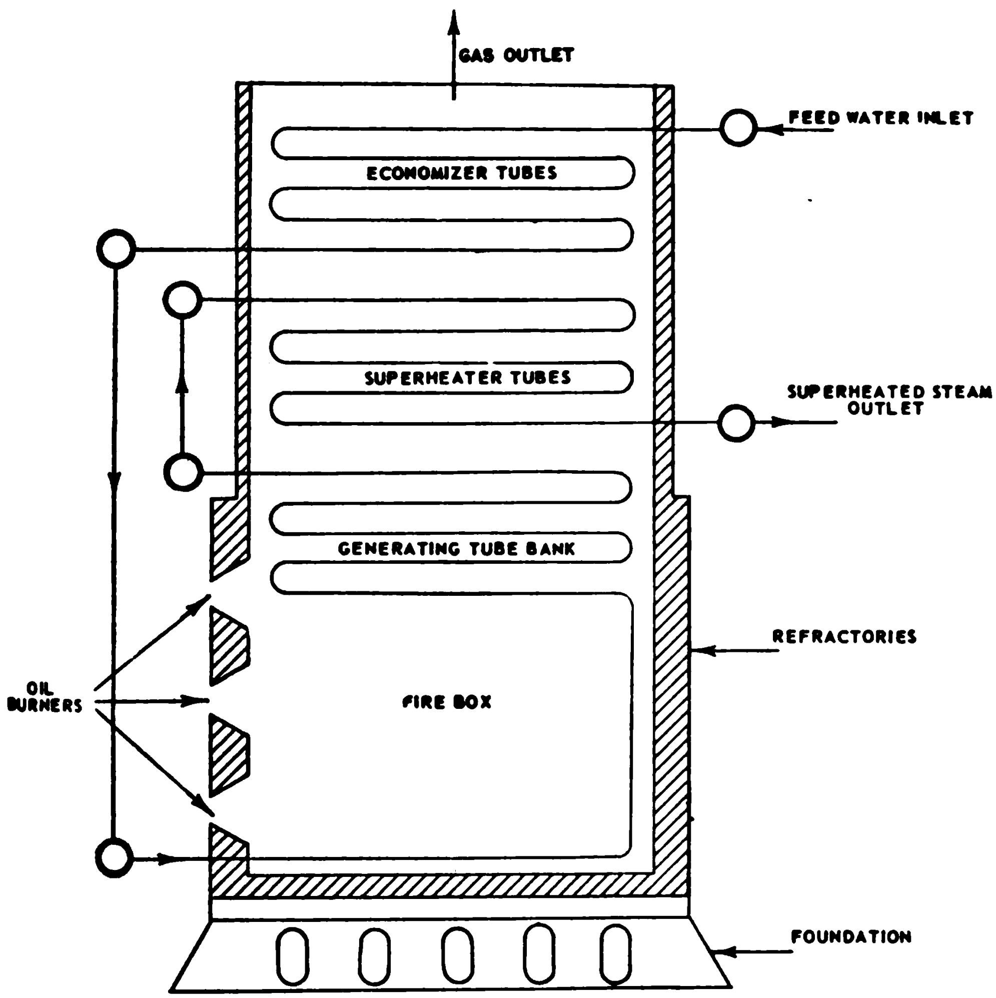


Figure 2–17.—Forced circulation (once-through) boiler.

In the boiler shown in figure 2–18, more water is pumped through the circuits than is converted into steam. The excess water—that is, the water which is not evaporated—is forced through the boiler circuits again by means of a recirculating pump. This type of boiler is sometimes known as a FORCED RECIRCULATION BOILER.

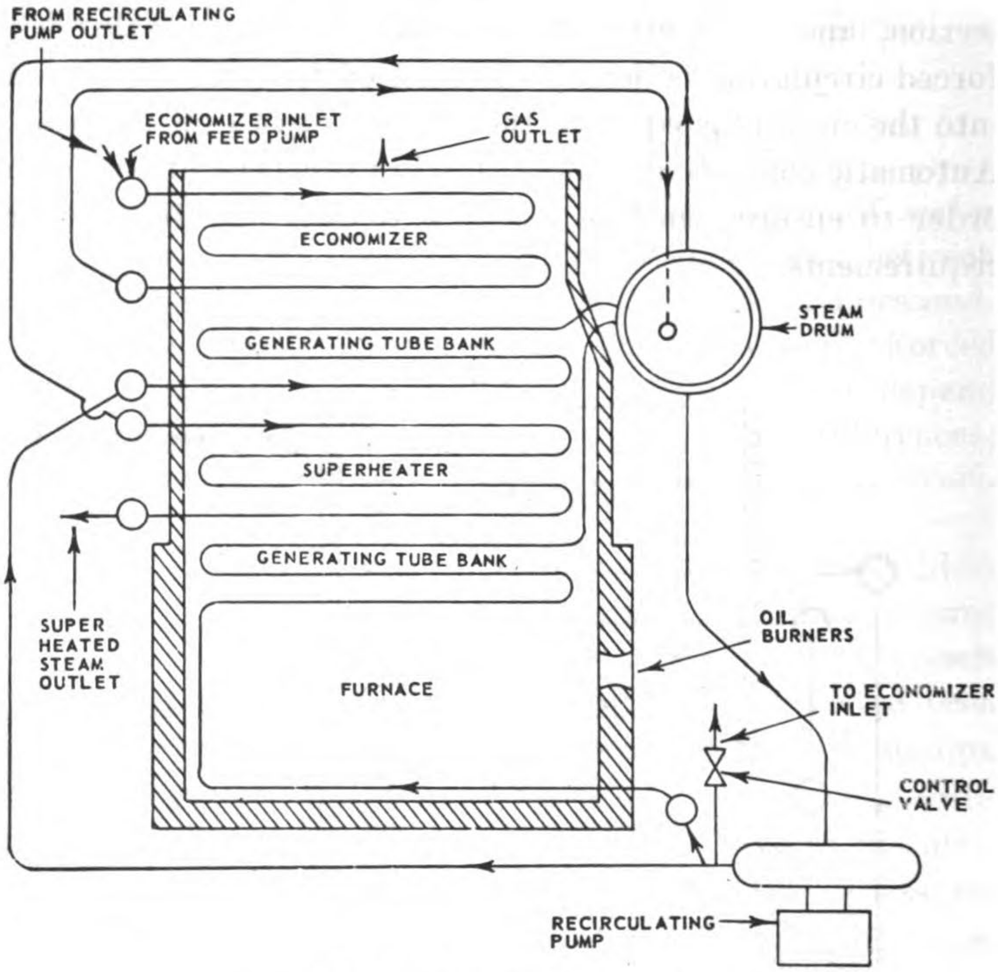


Figure 2–18.—Forced recirculation boiler.

The 1225-psi controlled circulation boiler which has recently been installed on some DL's has a conventional steam drum, with a feed pipe, steam separators and dryers, a desuperheater, a dry box (a V-shaped steel plate which serves the same purpose as the dry pipe on other types of boilers), and other fittings.

The boiler has a superheater, an economizer, and three

generating circuits. One generating circuit includes the side walls and the floor; the second circuit includes the primary evaporator and the rear wall; and the third consists of the secondary evaporator, which is divided into an upper and a lower section. Each section of the secondary evaporator has a separate inlet header, but the two sections have a common outlet header.

Two circulating pumps, fitted as integral parts of the boiler, provide positive circulation to all steam generating surfaces. One of the pumps is motor-driven, and the other is turbine-driven. Both pumps are connected in parallel to a single suction pipe from the steam drum. They discharge to a distributing header, from which the water flows to all three of the generating circuit inlet headers. The mixture of steam and water from the generating circuits enters the steam-isolating chamber of the steam drum. The steam passes through seven steam separators and dryers, and emerges above the water level in the steam drum. It is then led through the single-pass superheater, which is located between the primary evaporator and the lower section of the secondary evaporator. Main steam passes from the superheater outlet to the main steam line, and from there to the turbines; auxiliary steam goes back from the superheater to the desuperheater, which is submerged in the water space of the steam drum, and from there to the auxiliary steam line.

AUXILIARY BOILERS

The term AUXILIARY BOILERS is used to include a wide variety of small boilers which are used in Diesel-driven ships to supply steam for oil heaters, water heaters, distilling plants, laundry, galley, and for other auxiliary services. (It is important to note that an auxiliary boiler is one which is used for AUXILIARY SERVICES, rather than a boiler which is used on an auxiliary vessel. A propulsion boiler on an auxiliary vessel is NOT an auxiliary boiler.) Auxiliary boilers are not used on steam-driven ships, because the steam for auxiliary use is drawn from the propulsion boilers.

Auxiliary boilers are equipped with all required accessories and controls, and are arranged to operate as complete steam generating plants. Because they are such self-contained units, auxiliary boilers are often referred to as STEAM GENERATING UNITS or STEAM GENERATORS.

There are three basic types of auxiliary boilers: (1) fire-tube boilers; (2) water-tube natural circulation boilers; and (3) water-tube forced circulation boilers.

In fire-tube boilers, as has been noted, the gases of combustion flow through the tubes and thus heat the surrounding water. Fire-tube boilers are not used for propulsion of naval vessels, but only for auxiliary services. Water-tube auxiliary boilers are, of course, similar in principle to the water-tube propulsion boilers which have been described earlier in this chapter. However, auxiliary boilers are so varied in design and in method of operation that a knowledge of propulsion boilers will not, in itself, enable you to operate an auxiliary boiler. Detailed information concerning construction, operation, and maintenance of auxiliary boilers will be found in manufacturers' instruction books. These instruction books are carried on board ship, and must be consulted by personnel responsible for operating any auxiliary boiler.

QUIZ

1. What is meant by the term, LATENT HEAT OF VAPORIZATION?
2. Is the boiling point of water raised or lowered by an increase in pressure?
3. If steam at a saturation temperature of 400° F is superheated to 735° F, what is its degree of superheat?
4. What is the relationship between BOILER FULL-POWER CAPACITY and BOILER OVERLOAD CAPACITY?
5. What term describes the steam pressure at the final outlet from a boiler?
6. What are the three factors which limit the capacity of a boiler?
7. Which of the three limitations upon boiler capacity can actually be reached in a properly designed and properly operated boiler?

8. What factor is most important in determining the amount of fuel which can be burned properly and efficiently in a boiler furnace?
9. What causes water and steam circulation in a water-tube natural circulation boiler?
10. In modern express boilers, what purpose is served by downcomers?
11. Do M-type and DE-type natural circulation boilers have free or accelerated circulation?
12. What advantages does a controlled superheat boiler have over an uncontrolled superheat boiler?
13. Why is there no desuperheater on an M-type boiler?
14. What purpose is served by an economizer?
15. How are the superheater tubes of an uncontrolled superheat boiler protected from heat damage, after fires have been lighted but before sufficient steam has been generated to ensure a flow through the superheater?
16. What designation is given to a generating tube which is the fourth from the front, in the third row away from the furnace, in the left-hand tube bank as you face the front of the boiler?
17. At what angle do generating tubes usually enter the steam and water drums of naval boilers?
18. What purpose is served by the gill rings or fins on economizer tubes?
19. Why are boilers fitted with sliding feet?
20. What grade of firebrick is used for furnace walls which must withstand unusually severe operating conditions?
21. What refractories are used around burner openings?
22. Which of the refractory materials used in boiler furnaces can withstand the greatest temperature drop from its hot side to its cold side?
23. How is water circulation achieved in a forced circulation boiler?
24. Why is greater flexibility of design possible in a forced circulation boiler than in an natural circulation boiler?
25. How much water is pumped through the boiler circuits of a once-through forced circulation boiler?
26. What three basic types of auxiliary boilers are used in naval vessels?
27. In what types of naval vessels are auxiliary boilers used?

CHAPTER 3

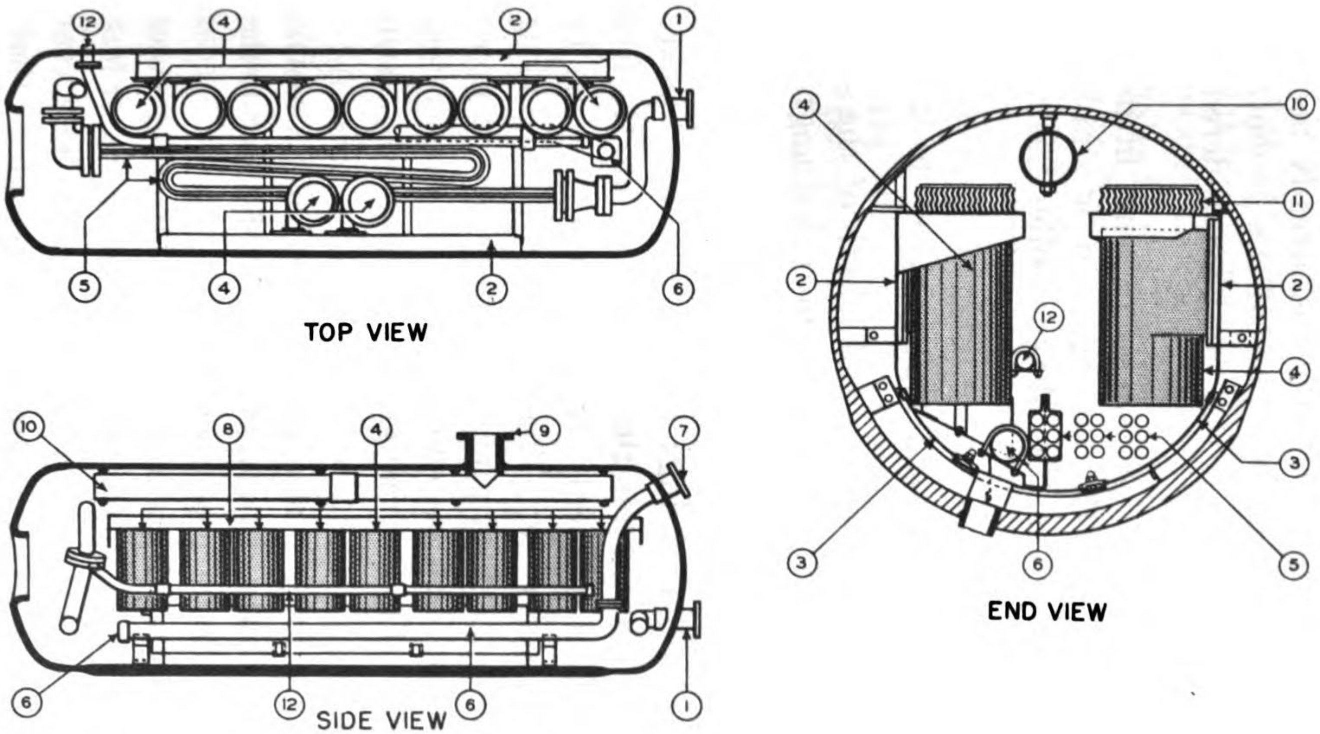
BOILER FITTINGS

The term BOILER FITTINGS is used to describe a number of attachments which are immediately or closely connected to the boiler, and which are required for the operation and control of the boiler. Internal feed pipes, dry pipes, steam separators, smoke indicators, soot blowers, water gage glasses, automatic feed water regulators, and a variety of valves and connections are classified as fittings. The term BOILER ACCESSORIES is usually applied to equipment which supplies service to the boiler. Burners, feed water pumps, fuel oil pumps, fuel oil heaters, and forced draft blowers are examples of boiler accessories.

Boiler fittings are generally divided into two categories: INTERNAL FITTINGS, which are installed inside the steam and water spaces of the boiler; and EXTERNAL FITTINGS, which are installed outside the steam and water spaces. In this chapter we will take up some of the internal and external fittings which are used on modern naval boilers. The gages and instruments which are required for boiler operation are often classified as fittings; however, they will be discussed separately in chapter 4. Description of boiler accessories will be found in various other chapters throughout this book.

INTERNAL FITTINGS

The internal fittings for naval boilers which we will take up here are: (1) the internal feed pipe; (2) the surface blow



1. DESUPERHEATER INLET
2. NOZZLE PLATES OF MANIFOLD BAFFLE
3. REMOVABLE APRON PLATES OF MANIFOLD BAFFLE
4. CYCLONE SEPARATORS
5. DESUPERHEATER TUBES
6. INTERNAL FEED PIPE
7. FEED NOZZLE
8. STEAM SCRUBBER SUPPORT
9. MAIN STEAM CONNECTION
10. DRY PIPE
11. STEAM SCRUBBERS
12. SURFACE BLOW LINE

Figure 3–1.—Cross sections showing internal fittings (destroyer escort boiler).

line; (3) baffles and swash plates; (4) cyclone steam separators; and (5) the dry pipe.

The desuperheater is sometimes classified as an internal boiler fitting, since it is installed in the steam drum. In this book, however, the desuperheater has already been described in chapter 2 as an integral part of the uncontrolled superheat type of boiler; and it will not be considered here as a boiler fitting.

Figure 3–1 shows the arrangement of internal fittings in a destroyer escort boiler. The arrangement is similar in the **M**-type boiler, except that the **M**-type boiler has no desuperheater.

Internal Feed Pipe

The INTERNAL FEED PIPE runs the full length of the steam drum. It is installed in the water space near, but not touching, the bottom of the drum. One end of the internal feed pipe connects through either the front or the rear drum head to the economizer outlet piping; the other end is blanked off. The feed water flows from the economizer into the feed pipe, and is distributed evenly throughout the drum by way of holes in the feed pipe. These holes are drilled along the entire length of the feed pipe. They are on the upper side only, so that the feed water discharges upward rather than downward. This arrangement has two main advantages:

1. The incoming feed water causes the least possible interference with the natural circulation of water in the boiler when it discharges upward.
2. The relatively cool incoming water is directed away from the hot steam drum metal, in order to reduce the possibility of setting up metal stresses. This consideration is of particular importance at high combustion rates.

In order to avoid restricting the flow of feed water into the drum, the total area of the holes must be equal to about twice the cross-sectional area of the feed pipe. In the **M**-

type boiler, the internal feed pipe is usually about 4 inches in diameter.

Surface Blow Line

The SURFACE BLOW LINE (or, as it is sometimes called, the INTERNAL BLOW PIPE) is a perforated pipe which, like the internal feed pipe, extends the full length of the steam drum. It is located about half an inch below the normal water level. The holes in the line are located along the upper side only.

The surface blow line is used to remove grease, scum, and light solids from the boiler water. One end of the line is blanked off; the other is connected through the drum head or wall to the surface blow valve. When the surface blow valve is opened, the pressure of the steam forces the water above the blow line through the holes, into the line, and out of the boiler.

In some older types of boilers, a shallow SCUM PAN is attached to the surface blow line. In this type of installation, the surface blow line holes are on the lower side.

BAFFLES AND SWASH PLATES

Various kinds of baffles may be installed inside the steam drum in order to direct the flow of steam or water, ensure adequate circulation throughout the drum, and prevent violent agitation of the water. Most steam and water baffles are removable.

STEAM BAFFLES may consist of steel plate deflectors, perforated steel plates, or labyrinthed steel screens. The perforated steel plate type of baffle is installed horizontally (or almost horizontally) just below the surface of the water; you can see this type of baffle in the steam drum of the destroyer escort boiler shown in figure 2–8. The labyrinthed steel screen type of baffle consists of several sinuous steel plates; these plates are installed quite close together, and are placed so that the steam must follow the labyrinths between the plates.

Figures 3–2 shows an arrangement of steam baffles in a boiler steam drum.

WATER BAFFLES are occasionally used in the steam drum to guide the relatively cool feed water to the downcomers, after it is discharged from the internal feed pipe. Water baffles are not commonly used on modern naval boilers.

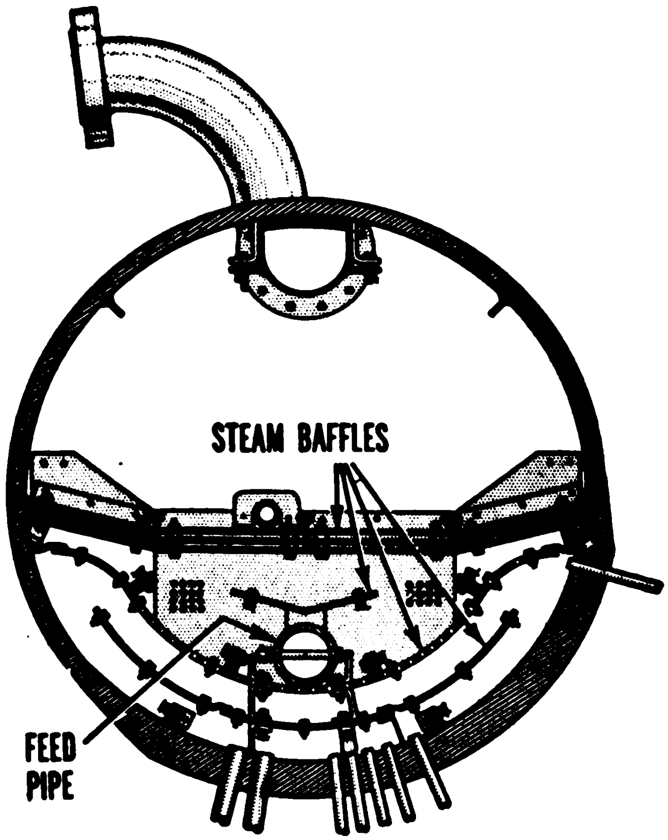


Figure 3–2.—Arrangement of steam baffles in boiler steam drum.

SWASH PLATES are used in some types of boilers to prevent excessive surging of the water from one end of the drum to the other. Swash plates are installed vertically, across the lower half of the drum. A space is left between the swash plate and the drum, so that the water can flow past the plate at a restricted rate.

Swash plates are seldom used in modern naval drum-type boilers, since they would restrict the flow of water to the downcomers and, in general, interfere with circulation in the steam drum. Drum-type boilers are usually installed with the long axes of the drums fore and aft, rather than athwartships, in order to prevent the water surging from

one end of the drum to the other as the ship rolls. Many header-type boilers, however, are installed with the steam drum athwartships; and swash plates are often used in boilers of this type to prevent excessive surging. (Notice the swash plate in the steam drum of the header-type boiler shown in figure 2–9.)

Cyclone Steam Separators

Most modern boilers are equipped with CYCLONE STEAM SEPARATORS which utilize centrifugal force to separate the steam from the water inside the steam drum. There are generally eighteen separators, nine on each side of the drum. Cyclone separators must NEVER be removed from the steam drum unless absolutely necessary.

The cyclone separators are attached to a manifold baffle which extends from just forward of the generating tubes to just aft of them. (It does not reach as far as the downcomers.) The baffle curves around the lower half of the drum, passing just below the internal feed pipe, and leaves a space of about 3 inches between the baffle and the drum. The forward and after ends of this space are closed by a sealing bar attached to the drum. The baffle is attached to the drum by means of two flat bars which hang from the drum, one on each side; the bars extend the full length of the baffle. Each bar contains nine ports, or openings, and a cyclone steam separator is placed over each port.

The general arrangement of the manifold baffle and the cyclone steam separators was shown in figure 3–1. Now look at figure 3–3, and trace the flow of steam and water through the steam drum. The generating tubes discharge a mixture of steam and water into the space between the manifold baffle and the drum. Since this space is entirely enclosed, the only passage available for the steam and water is through the ports which open to the cyclone separators. As the mixture passes through the separators, the steam passes upward and the water discharges downward.

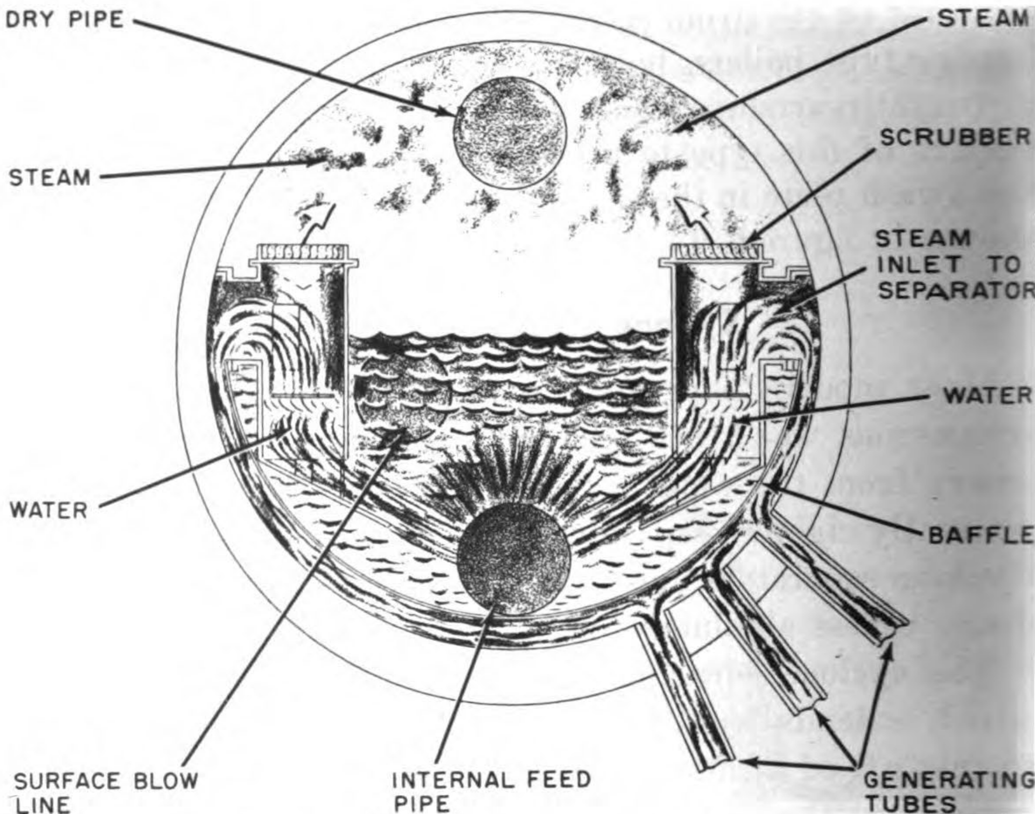


Figure 3–3.—Flow of steam and water in the steam drum.

The cyclone steam separator is shown in cutaway view in figure 3–4. The mixture of steam and water enters the separator through the inlet connection, at a tangent to the separator body. Because of its angle of entrance, the steam and water mixture acquires a rotating motion. As the mixture whirls around, the water is separated from the steam by centrifugal force. The water, being heavier, is thrown out to the sides of the separator; the steam, being lighter, stays toward the center. An internal baffle serves to deflect the steam to the center and the water to the outside. The steam then rises through the center of the separator, passing through the scrubber element. The scrubber consists of closely spaced corrugated steel plates. As the steam passes through the scrubber, its direction is continuously changed; and at each change of direction some moisture is lost. The steam then rises to the top of the steam drum, where it is picked up by the dry pipe.

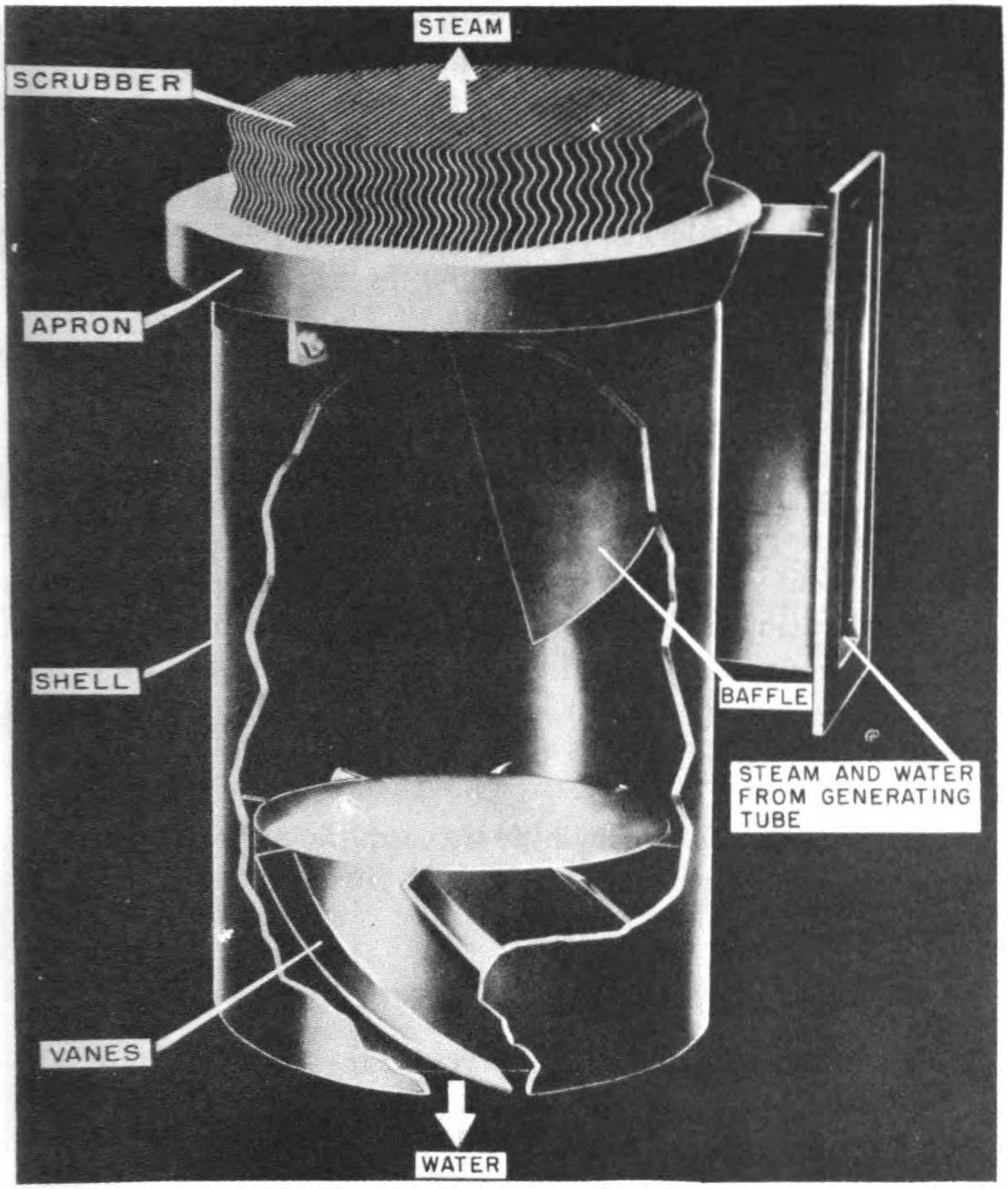


Figure 3–4.—Cyclone steam separator (cutaway view).

While the steam is rising, the water is gradually falling to the base of the separator. Stationary curved vanes in the bottom of the separator serve to maintain the rotating motion of the water until it is finally discharged from the bottom of the separator. The vanes are located around the periphery of a flat plate, so that the water passes from the separator only around the outer edge. The flat plate also serves to

prevent the steam (which is in the center of the separator) from being carried downward with the water.

A flat baffle is fitted at the base of each of the two end separators on each side. This baffle guides the water which is being discharged from the separator to the center of the drum, where it mixes thoroughly with the rest of the water; without such a baffle, the water from these end separators would flow directly to the downcomers.

Dry Pipe

The DRY PIPE is a steel pipe about 5 or 6 inches in diameter. It is installed along the centerline of the steam drum, and runs almost the entire length of the drum. Both ends of the dry pipe are closed. Steam enters by way of holes or slits which are cut along the entire length of the upper surface. The perforations are made in the upper surface only, so that the steam must make a sudden change of direction in order to enter the dry pipe. Some moisture is lost when the steam changes direction; so the dry pipe is, in effect, a steam separator.

The steam leaves the dry pipe through the main steam outlet and, in superheat control boilers, through the auxiliary steam outlet.

COCKS AND VENTS

Various types of cocks and vents are required for the proper operation of a boiler. These cocks and vents are classified as EXTERNAL FITTINGS.

A high-pressure globe valve is installed at the highest point of the boiler steam drum to serve as an AIRCOCK. It allows air to escape when the boiler is being filled, or when steam is first forming in the drum. In addition, the aircock allows air to enter the drum when the boiler is being emptied.

The SALINITY COCK is used to draw off samples of boiler water for tests. It consists of a valve which is fitted to the bottom blow connection between the bottom blow valve and the water drum. A sample cooler is usually fitted to the

outlet side, to cool the test water below the boiling point (at atmospheric pressure) as it is being drawn off.

SUPERHEATER VENTS and SUPERHEATER DRAINS are shown in figure 2–5, in the previous chapter. As you can see, the vents are installed at or near the highest point on each header; the drains are installed at or near the bottom of each header. The drains discharge either to the atmosphere or into the high-pressure drain system.

BLOW VALVES

Some solid matter is always present in boiler water. Most of the solid matter is heavier than water; in the boiler, therefore, it settles in the water drums and headers. Some of the solid matter is lighter than water; and this rises, forming a scum on the surface of the water in the steam drum. As makeup feed water is brought in to replace water lost from the system, the concentration of solids remaining in the boiler gradually increases, with consequent loss of boiler efficiency and possible danger to boiler parts.

Blow lines and blow valves are used to blow this solid

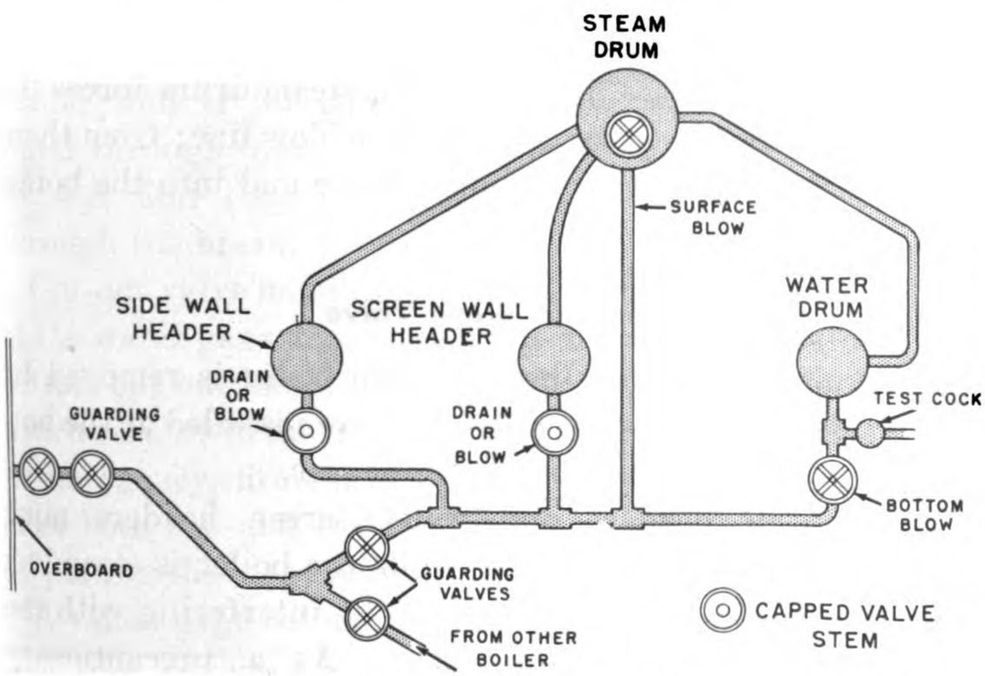


Figure 3–5.—Boiler blow piping.

matter overboard, and thus reduce the concentration in the boiler. Light solids and scum are removed from the surface of the water by means of the surface blow line and the surface blow valve. Heavy solids and sludge are removed by means of the bottom blow valves.

Both the surface blow and the bottom blow valves discharge to a system of BOILER BLOW PIPING such as that shown in figure 3–5. The boiler blow piping line is common to all boilers in the fireroom. Guarding valves are installed in the line as protection against leakage from a steaming boiler into the blow piping and leakage from the blow piping back into a dead boiler. Another guarding valve, installed at the outboard bulkhead of the fireroom, affords protection against salt water leakage into the blow piping; this guarding valve is connected to an OVERBOARD DISCHARGE VALVE (sometimes called a SKIN VALVE), which leads overboard below the ship's waterline.

Surface Blow Valve

Light solids, scum, and oil or grease are removed from the surface of the water in the steam drum by means of the surface blow line and the SURFACE BLOW VALVE, which is connected to the surface blow line. When the surface blow valve is opened, steam pressure in the steam drum forces the scum and other matter into the surface blow line; from there it passes through the surface blow valve and into the boiler blow piping system.

Bottom Blow Valve

Solid matter which is heavier than water is removed by means of BOTTOM BLOW VALVES, which are installed at the bottom of each water drum and water header.

Water wall headers and water screen headers must NEVER be given a bottom blow while the boiler is steaming, since this would endanger the tubes by interfering with the normal circulation of the water. As a precautionary measure, bottom blow valves for water wall headers and

water screen headers are not fitted with handwheels. The valve stem usually has a cap which must be removed before the valve can be operated. The valve is then opened and closed with a special wrench or a portable handwheel.

WATER GAGE COLUMNS

Every boiler has at least two independent devices for indicating the water level in the steam drum. Older boilers, operating at pressures of less than 250 psi, generally had one tubular water gage and a series of trycocks. Modern high-pressure boilers use two separate water gage assemblies, as described below.

The water gages used in modern boilers are made of glass strips, ground to flat, parallel faces. The glass strips are backed up by thin sheets of mica which separate the glass from the high temperature steam and water, and thus prevent etching of the glass or shattering of the glass in case of breakage. The entire assembly of glass and mica strips is supported between two steel cover plates, which are held together by studs. The water gage has a valve in the bottom connection, consisting of a ball which rests on a holder just above the bottom valve stem. As long as there is equal pressure on each side of the ball, the ball remains in its holder; but if the gage glass breaks, the sudden rush of water through the bottom connection forces the ball up onto its seat and thus prevents further escape of hot water through the break.

Cut-out valve handles (levers) are fitted at top and bottom of the water gage glasses, and are connected by chains. The bottom cut-out handle has, in addition, a long loop of chain which reaches to the lower floor plates of the fireroom. Thus, in emergency, fireroom personnel on the lower grating can close both top and bottom cut-out valves in one operation, by pulling the long chain.

A water gage column is shown in figure 3–6; a cross-section view is shown within the dotted circle. It should be mentioned that the regulator connections shown at top and

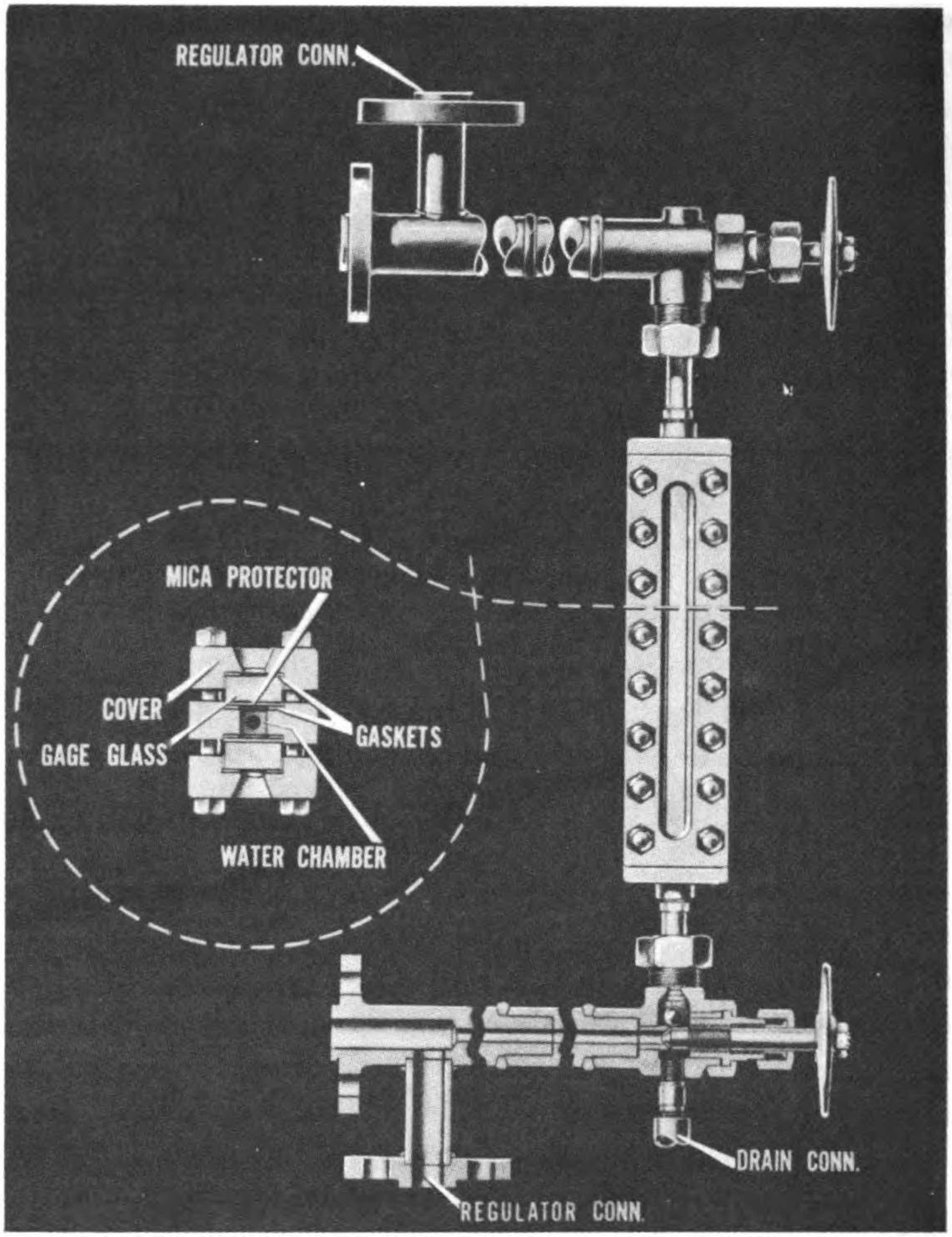


Figure 3–6.—Water gage column.

bottom are not found on all gage glasses; they are installed only on boilers which have been fitted with feed water regulators, but which were not originally designed to use feed water regulators.

As mentioned before, each boiler has two independent means of showing the water level in the steam drum. In modern high-pressure boilers, the two devices are: (1) a

10-inch glass; and (2) two 10-inch glasses, mounted side by side, but overlapped in such a way that the distance from the bottom of the lower glass to the top of the upper glass is 18 inches. In both cases, the measurements refer to the vertical distance between the bottom and the top of the transparent glass. In modern installations, each assembly is mounted so that the center is located at normal water level; in some older boilers, however, the normal water level is NOT at the middle of the gage.

A light is usually placed behind the water gage so that you can see the water level easily. Some glasses are corrugated on the outside in such a way as to make the part of the column which is covered with water appear to be darker than the rest; these corrugated glasses are known as REFLEX glasses.

The 18-inch assembly is used as a check on the 10-inch water gage glass. The allowable high-water and low-water levels can be seen in the 10-inch glass. If the water is out of sight in the 10-inch glass, you may still be able to see it in the 18-inch glass, and to correct the situation by increasing or decreasing the amount of feed water to the boiler. If the water is out of sight in both glasses, the situation must be treated as an emergency, according to the high-water and low-water casualty procedures discussed in the chapter on fireroom casualty control.

Water gage glasses must be BLOWN DOWN before the boiler is cut in on the steam line, at the end of each watch, and at any time when there is any question as to the water level in the boiler. Frequent blowing down is necessary because the gage connections are easily clogged with scale, dirt, or other solid matter which, if not removed, would lead to a false indication of water level in the gage glasses. The procedure for blowing down water gage glasses is given in the chapter on fireroom operations. Maintenance and replacement of water gage glasses is discussed in the chapter on boiler maintenance and repair.

FEED STOP AND CHECK VALVES

Each boiler has either one or two combined FEED STOP AND CHECK VALVES for controlling the amount of water admitted to the boiler. If two sets of valves are installed, only one is used at any given time; the other is kept in readiness for immediate use in case of casualty to the feed system or to the feed stop and check valves ordinarily used.

When two sets of valves are installed, each one is connected to a separate feed line. On a boiler which has no economizer, the valves discharge directly to the internal feed pipe. On a boiler which does have an economizer (and, in fact, almost all modern boilers do have them), the feed stop and check valves discharge to the economizer inlet. When the feed stop and check valves discharge to the economizer inlet, a check valve is usually installed in the line between the economizer outlet and the internal feed pipe connection; this valve allows the feed water to flow into the boiler, but prevents water and steam from flowing into the economizer from the steam drum.

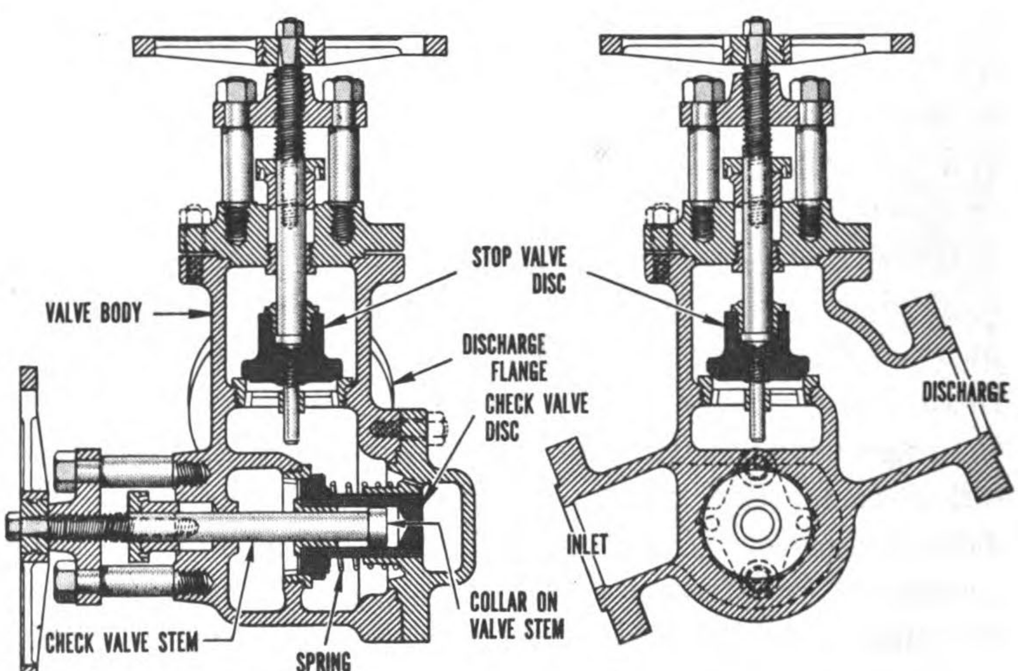


Figure 3–7.—Combined feed stop and check valves.

Combined feed stop and check valves are shown in figure 3–7. As you can see from this illustration, the unit consists of two separate valves—the stop valve and the check valve. Sometimes the two valves are housed in a single body; in other installations, each valve has a separate body but the two are bolted together. The combined feed stop and check valves are always installed with the stop valve between the check valve and the economizer inlet line, so that the stop valve may be closed if the check valve fails to function.

In ordinary operation, when the boiler is steaming, the stop valve is kept fully open and the check valve is used to regulate the supply of feed water. Both valves are operated manually, by turning the hand wheels.

AUTOMATIC FEED WATER REGULATORS

Many modern boilers have AUTOMATIC FEED WATER REGULATORS for controlling the supply of feed water to the boiler. Three general types of automatic feed water regulators are in use on naval boilers: single-element regulators, two-element regulators, and three-element regulators.

Where single-element regulators are installed, their use is mandatory when the ship is operating under battle conditions, where manual feeding of the boiler might become difficult or impossible. The single-element regulators must be cut in immediately when general quarters is sounded. They may also be used when the ship is cruising under normal conditions; and, in fact, it is essential that they be operated frequently enough to ensure their proper functioning under battle conditions. Single-element regulators can control the water level within acceptable limits under relatively steady steaming conditions; but under severe maneuvering conditions it may be necessary to resort to manual feed control. Since complete reliance cannot be placed in the single-element regulator, a checkman must remain on station and be ready to take manual control, when the single-element regulator is in use under normal cruising conditions.

Multi-element automatic feed water regulators, which are

being used increasingly in the Navy, are much more successful in controlling the water level in the boiler. When two- or three-element regulators are installed, their use is required at all times. Primary reliance for control of the water level must be placed in the multi-element regulator, and NOT in manual operation of the feed check valve. When a multi-element feed water regulator is in service, it is not necessary to have a checkman stationed at the feed check valve. All boilers equipped with multi-element regulators are also equipped with remote water level indicators, which are installed at the lower level where they can be observed by the man in charge of the watch.

The essential difference between single-element regulators and multi-element regulators lies in the fact that single-element regulators are controlled ONLY by the existing water level in the steam drum, whereas multi-element regulators are controlled by the existing water level PLUS one or two other factors. Because of these additional factors, multi-element regulators are able to compensate for the changes in boiler water volume which occur as a result of changes in the firing rate. As the firing rate is increased, there is an increase in the volume of the water. This increase, which is known as SWELL, occurs because there is an increase in the number and size of the steam bubbles below the surface of the water. As the firing rate is decreased, there is a decrease in the volume of the water. This decrease, which is known as SHRINK, occurs because there are fewer steam bubbles in the water and they are of smaller size. Thus, for a fixed WEIGHT of boiler water, the VOLUME will vary with the rate of combustion.

The single-element regulator, being controlled only by the existing water level in the steam drum, lags behind the actual requirements of the boiler when the firing rate is changing rapidly. Since it cannot compensate for swell or shrink, it decreases the feed supply immediately after the firing rate is increased; and it increases the feed supply immediately after the firing rate is decreased. Thus the single-element regulator tends to momentarily underfeed the

boiler when the firing rate is increased, and to momentarily overfeed the boiler when the firing rate is decreased.

Multi-element regulators are also controlled by the existing water level in the steam drum. However, they compensate for the effects of swell and shrink by the use of additional control factors.

Single-Element Regulators

The single-element feed water regulators which are currently used by the Navy are of three types. Each type has a control element which varies the supply of feed water to the boiler by actuating a feed-regulating valve in the feed line, or by actuating a steam control valve in the steam line to the feed pump. The regulators are classified as thermal-mechanical, thermal-pneumatic, or thermal-hydraulic, depending upon the type of control element used; but in each type the operation of the control element is governed solely by the existing water level in the steam drum.

The control element in a single-element THERMAL-MECHANICAL REGULATOR consists of two expansion tubes mounted in the form of a **V** on the front of the steam drum. The upper end of the element is connected to the steam drum above the water level, and the lower end is connected below the water level. The water level in the tubes is always the same as the water level in the steam drum; thus, as the water level drops in the drum it also drops in the tubes, leaving more room for steam. Due to the exposed tubing, the water cools to a slightly lower temperature than the steam.

Thus, the expansion of the tubes is directly related to the amount of steam which is present at any given moment in the tubes. When the water level is low, there will be more steam in the tubes—hence the tubes will expand. When the water level is high, there will be less steam in the tubes—hence the tubes will contract. The motion caused by the expansion or contraction of the tubes is magnified by means of levers, and is employed to operate a feed-regulating valve installed in the feed line.

The control element in a single-element THERMAL-PNEUMATIC REGULATOR consists of a single inclined tube. This tube expands and contracts according to the water level, in a manner similar to that described for the single-element thermal-mechanical type. The expansion and contraction of the tube is employed to operate an air pilot valve which actuates a feed water regulating valve (or a pump governor) by supplying compressed air at pressures which vary according to the water level.

The control element in a single-element THERMAL-HYDRAULIC REGULATOR is called a GENERATOR. It consists of a jacketed tube. The tube is connected to the steam drum above and below the water level, and any change in water level in the drum causes a corresponding change in water level in the tube. The jacket, or outer tube, surrounds the inner tube and is connected by copper piping to the regulating valve, forming a closed system. The jacket is filled with water. The presence of steam and water in the inner tube causes a certain amount of water in the outer tube to flash into steam, thus creating a pressure in the jacket. A drop in the steam drum water level allows more steam to enter the inner tube, and this in turn causes more water in the jacket to flash into steam, thus increasing the pressure in the jacket. The increased pressure in the jacket is transmitted to the bellows near the top of the regulating valve; the valve stem is forced down against a spring, and the feed water regulating valve is opened.

When the water level in the steam drum has been restored to normal, the water level rises in the inner tube and thus decreases the pressure in the outer tube or jacket. Since the jacket, tubing, and bellows form a closed system, the reduction of pressure in the jacket causes a reduction of pressure on the bellows. The spring pressure lifts the valve stem and partially closes the valve.

Thus it may be seen that the position of the feed water regulating valve is determined by the relationship between the jacket pressure and the spring pressure. When the jacket

pressure is greater, the valve opens. When the spring pressure is greater, the valve tends to close.

A single-element thermal-hydraulic feed water regulator is shown in figure 3–8. Note that the feed water regulating valve is installed in the main feed line, between the feed stop and check valves and the economizer. When the automatic regulator is in use, the stop and check valves must be fully open; when the automatic regulator is not in use, the

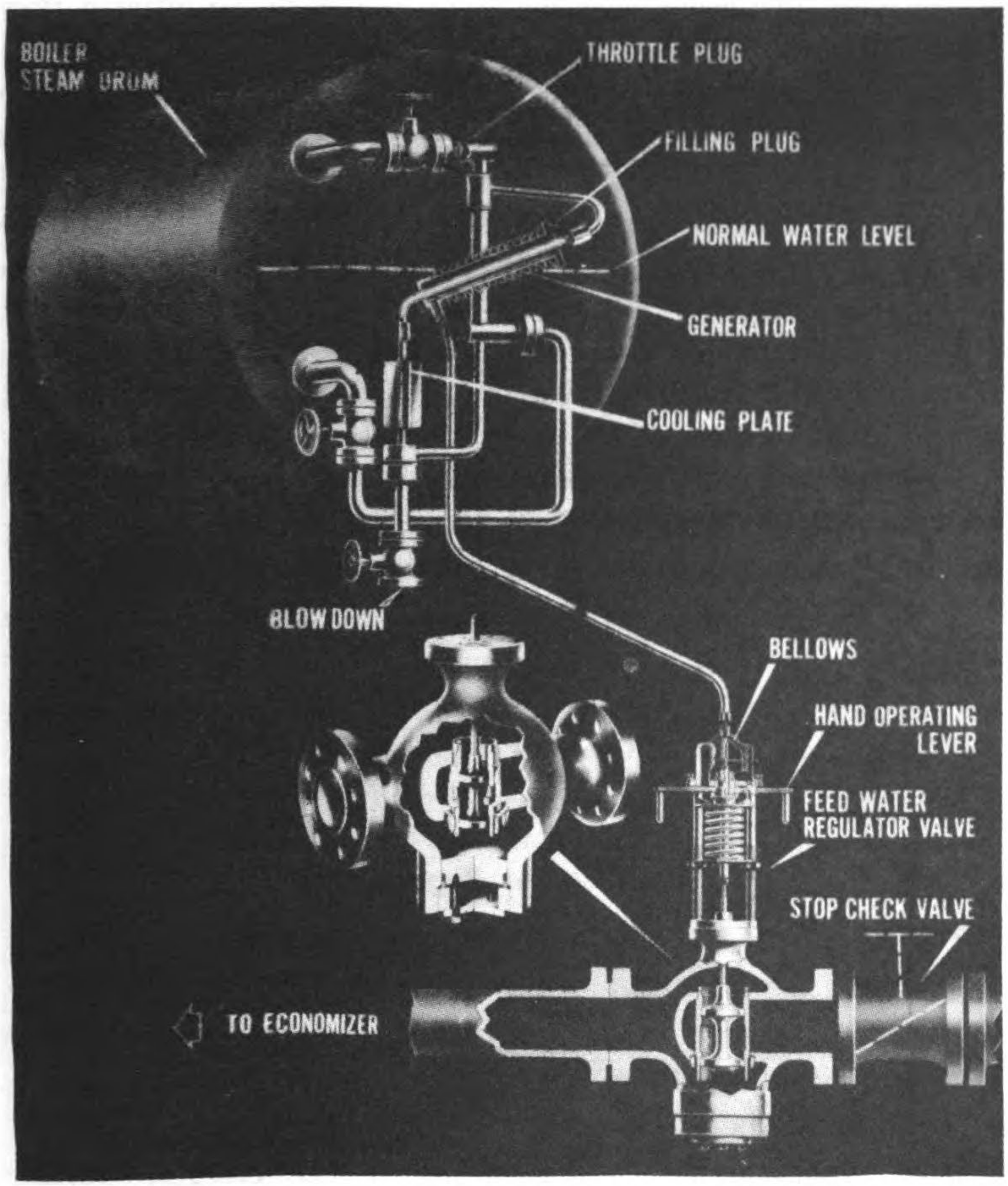


Figure 3–8.—Single-element thermal-hydraulic feed water regulator.

regulating valve must be fully open so that the boiler may be fed manually.

Two-Element Regulators

There are two types of two-element automatic feed water regulators: (1) the thermo-mechanical type, and (2) the thermo-pneumatic type. Both types use a steam-flow correction to compensate for the effects of swell and shrink.

In the two-element THERMO-MECHANICAL regulator, the steam-flow correction is based upon the rate of steam flow from the boiler, as measured by the pressure differential between the superheater inlet and the superheater outlet. The action of each element is transmitted mechanically, by means of lever arms, to the valve which controls the flow of feed water. The relative influence of either water level or rate of steam flow can be adjusted by changing the lengths of the lever arms.

The two-element THERMO-PNEUMATIC regulator uses the RATE OF CHANGE, rather than the pressure differential, as a steam-flow correction for the water-level element. One controller transmits to receiving controllers an air pressure which is proportional to the pressure differential existing between the superheater inlet and the superheater outlet. The receiving controllers transform this proportional air pressure indication into an impulse which is a measure of the rate of change in steam flow through the superheater. The rate-of-change effect is then combined with the water-level effect, to control the flow of feed water to the boiler.

Three-Element Regulators

The three-element feed water regulator is even more effective than the two-element regulator in compensating for swell and shrink. In addition, the three-element regulator is able to maintain the correct water level in spite of rolling or pitching of the ship.

Most three-element regulators are of the THERMO-PNEUMATIC type. The feed water control valve is operated by an

air impulse or signal from a combining relay. This impulse or signal is the resultant of signals received from three different elements, each of which is sensitive to changes in one operating condition. The three operating conditions which influence a three-element regulator are:

1. STEAM DRUM WATER LEVEL. The water level in the steam drum affects a thermostatic expansion tube; this tube operates a pilot valve which sends an air signal to the combining relay.

2. STEAM FLOW FROM THE BOILER. The pressure drop across the superheater is transmitted to the combining relay from a high-pressure reservoir located on the steam drum and a low-pressure reservoir located on the main steam outlet header. As the steam flow increases or decreases, the pressure differential increases or decreases. The receiver element in the combining relay is positioned to adjust the outgoing air signal accordingly.

3. FEED WATER FLOW TO THE BOILER. The pressure drop between the inlet and the outlet of the economizer is transmitted to the combining relay. As the water flow through the economizer increases or decreases, the increase or decrease in pressure differential positions the receiver element in the combining relay to adjust the outgoing air signal accordingly.

STEAM STOP VALVES

After steam has been generated in the boiler and collected in the steam drum, it is drawn off through STEAM STOP VALVES. Two steam stop valves are fitted to each boiler—one for main steam, and one for auxiliary steam. In addition, turbogenerator steam stop valves are installed in those ships which have separate turbogenerator steam lines.

Main-Steam Stop Valve

The MAIN STEAM STOP VALVE is used to cut the boiler in on the main steam line or to disconnect it from the line. The valve is always either fully opened or fully closed. The

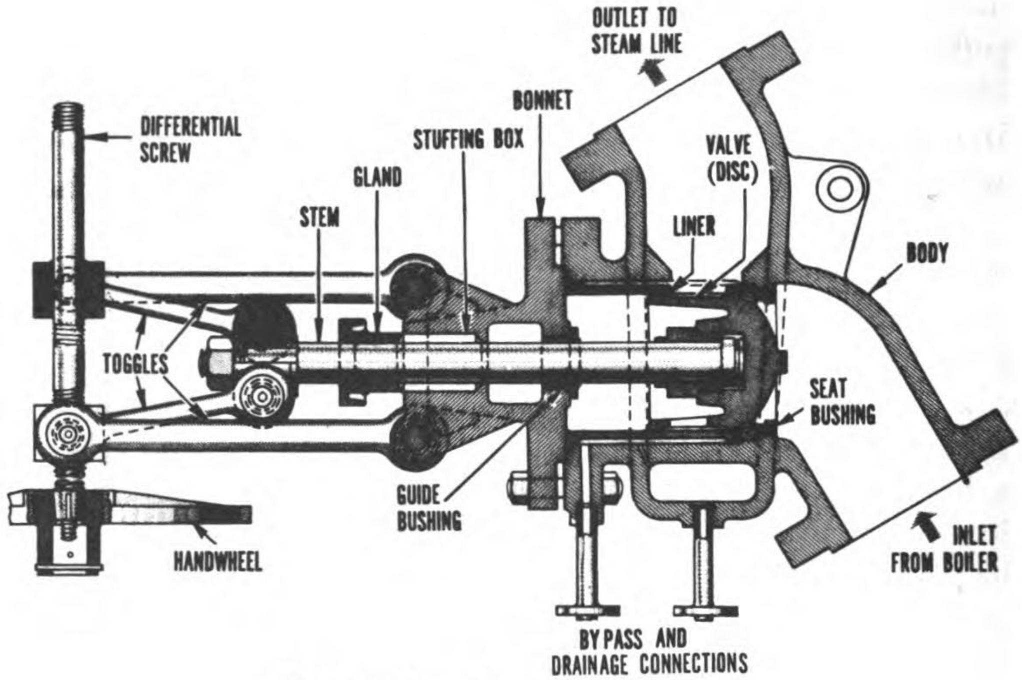


Figure 3–9.—Main steam stop valve.

main steam stop valve can be operated either at the valve itself or from a remote control station in an adjacent compartment or on the deck. (In some installations, the main steam stop valve may be closed, but not opened, by a remote control device.)

The main steam stop valve is usually a toggle-operated globe valve, of the type shown in figure 3–9. It is specially designed for high-pressure and high-temperature service. The seating surfaces of the valve disk and seat are usually made of STELLITE—a hard, erosion-resistant alloy containing cobalt, chromium, tungsten, and small amounts of iron, carbon, manganese, and silicon. Bypass and drainage connections are fitted to the underside of the valve body, on either side of the valve disk.

Auxiliary Steam Stop Valve

The AUXILIARY STEAM STOP VALVE is smaller than the main steam stop valve, but is otherwise very similar to it. In superheat control boilers (M-type), the auxiliary steam stop valve is connected directly to the steam drum, since

it is not necessary for auxiliary steam to pass through the superheater. In boilers with uncontrolled superheat, where all steam passes through the superheater and auxiliary steam then passes through a desuperheater, the auxiliary steam stop valve is located at the desuperheater outlet connection.

Turbogenerator Steam Stop Valves

The turbogenerator steam system, when installed, is very similar in general arrangement to the main steam system. The piping and valves are arranged so as to allow for either split-plant or cross-connected operation of the turbogenerators. The TURBOGENERATOR STEAM STOP VALVES which admit superheated steam to the turbogenerator line are located between the boiler and the main steam stop valve.

Turbogenerators are also provided with a saturated or auxiliary steam connection from the auxiliary steam system. However, turbogenerators should not be operated from the auxiliary line except in emergency.

SAFETY VALVES

Every boiler is fitted with SAFETY VALVES which prevent the steam pressure from rising above safe working limits. The safety valves installed on a boiler must be sufficient to reduce the steam drum pressure when the boiler is being operated at full firing rate and is completely disconnected from the steam lines. As a rule, boilers have either two or three safety valves on the steam drum and one on the superheater.

Several types of safety valves are used on naval boilers, but each is designed to open completely (POP) at a specified pressure, and to remain open until a specified pressure drop (BLOWDOWN) has occurred. Safety valves must close tightly, without chattering, and must remain tightly closed after seating.

It is important to understand the difference between safety valves and ordinary relief valves. The amount of pressure

required to lift a relief valve increases as the valve lifts, because the resistance of the spring increases in proportion to the amount of compression. If a relief valve were installed on a steam drum, therefore, it would open slightly when the specified pressure was exceeded; a small amount of steam would be discharged; and then the valve would close again. Thus a relief valve on a steam drum would be constantly opening and closing; and this repeated action would pound the seat and disk and cause early failure of the valve.

In order to overcome this difficulty, safety valves are designed to open completely at a specified pressure. Several different types of safety valves are used on naval boilers, but they all lift on the same general principle. In each case the initial lift of the valve disk or feather is caused by static pressure of the steam acting upon the disk or feather. As soon as the valve begins to open, however, a projecting lip or ring of larger area is exposed for the steam pressure to act upon. The resulting increase in force overcomes the resistance of the spring, and the valve pops—that is, it opens quickly and completely. Because of the larger area now presented, the valve reseats at a lower pressure than that which caused it to lift originally.

The various types of safety valves differ chiefly as to the method of applying compression to the spring, the method of transmitting spring pressure to the feather or disk, the shape of the feather or disk, and the method of blowdown adjustment. Detailed information on the operation and maintenance of safety valves can be found in the instruction books furnished by the manufacturers of this equipment.

The popping and reseating pressures of all safety valves are specifically authorized by the Bureau of Ships, and cannot be changed without Bureau approval.

Steam Drum Safety Valves

The three types of steam drum safety valves now in naval service are: (1) the huddling chamber type; (2) the nozzle reaction type; and (3) the jet flow type.

In the HUDDLING CHAMBER type of safety valve, static pressure of the steam in the drum acts upon the bottom of the feather, and causes the initial opening of the valve. The huddling chamber, which is between the valve seat and a restricting orifice, fills with steam as the valve opens. The steam in the huddling chamber builds up a static pressure which acts upon the extra area provided by the projecting lip of the feather, and causes the valve to open fully. After a predetermined drop in pressure (blowdown) the valve closes with a slight snap.

Blowdown adjustment in the huddling chamber type of valve is accomplished by raising or lowering an adjusting ring which shapes the huddling chamber. Raising the adjusting ring increases the amount of pressure drop (blowdown) which must occur before the valve will reseat; lowering the adjusting ring decreases the blowdown.

The NOZZLE REACTION type of safety valve is shown in figure 3–10. The initial lift occurs when the static pressure of the steam in the drum acts upon the disk insert with force sufficient to overcome the tension of the spring. As the disk insert lifts, the escaping steam strikes the nozzle ring and changes direction. The resulting force of reaction causes the disk to lift higher, up to about 60 percent of rated capacity. Full capacity is reached as the result of a secondary, progressively increasing lift which occurs as an upper adjusting ring is exposed. The ring deflects the steam downward, and the resulting force of reaction causes the disk to lift still higher.

Blowdown adjustment in the nozzle reaction type of valve is accomplished by raising or lowering the adjusting ring.

The JET FLOW type of safety valve utilizes both the reaction and the velocity of the escaping steam. The static pressure on the disk overcomes the spring tension and causes the initial flow of steam. The escaping steam strikes against a nozzle ring and discharges into the body of the valve. The resulting reactive force lifts the disk higher, and thereby increases the area of flow and the velocity of the steam. As the velocity increases, some of the steam discharges through

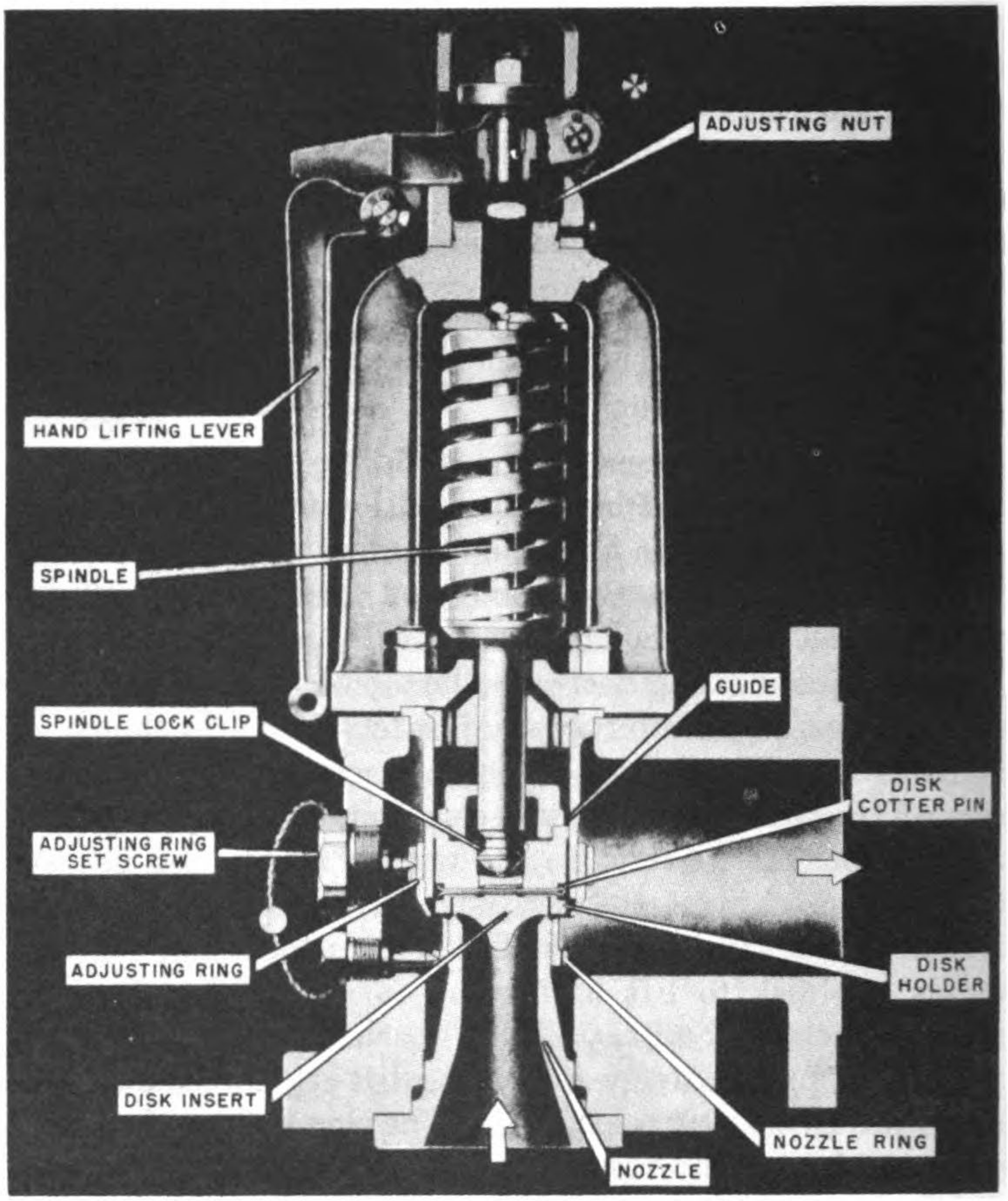


Figure 3–10.—Steam drum safety valve (nozzle reaction type).

orifices which are located around the lower end of an adjustable guide ring; thus an upward force is created and the valve is lifted still higher. The position of the disk at the time of popping is such that the area of discharge is greater than the area of the nozzle; and thus the accumulation of pressure which is required for full lift in the huddling chamber and nozzle reaction types of valves is unnecessary for full lift of the jet flow valve.

Blowdown adjustment in the jet flow valve is made by controlling the amount of steam which is allowed to flow through the orifices. The orifices are regulated by adjusting the positions of METERING DISKS. Since the metering disks can be adjusted by externally accessible screws, blowdown adjustment of the jet flow type of valve is quite easily accomplished.

Superheater Outlet Safety Valves

Safety valves must be installed on the superheater, as well as on the steam drum. Superheater safety valves are always set to lift and reseat at a lower pressure than the drum valves. If superheater pressure is not lowered when steam drum pressure is lowered, steam flow through the superheater will be diminished, stopped, or even reversed; and superheater tubes may overheat and burn out.

There are two basic types of superheater outlet safety valves now in naval service: (1) spring-loaded valves; and (2) pressure pilot-operated valves.

SPRING-LOADED SUPERHEATER OUTLET VALVES are used on some uncontrolled superheat boilers. For temperatures BELOW 700° F, these valves are very similar in general construction to the steam drum safety valves; the chief difference is that the superheater valve springs and bonnets are made of special heat-resistant alloys.

Some spring-loaded superheater safety valves are used on uncontrolled superheat boilers that operate at temperatures above 700° F. These valves have bimetallic thermal compensators which automatically compensate for the changes in steam density which occur with variations in temperature.

The superheat control type of boiler is fitted with a PRESSURE PILOT-OPERATED SUPERHEATER SAFETY VALVE ASSEMBLY. This assembly consists of three connected valves:

1. A small spring-loaded steam drum safety valve
2. A pilot, or actuating, valve
3. An actuated, or unloading, superheater valve

The spring-loaded drum safety valve and the pilot (or actuating) valve are installed on the steam drum. The

stem of the drum valve is connected mechanically, by means of a lever, to the stem of the pilot valve. The pilot valve is connected by piping to the space above the disk in the superheater outlet unloading (or actuated) valve. In addition, a hand operated valve is installed in the actuating line, so that the unloading valve on the superheater may be opened by hand if necessary.

A pressure pilot-operated superheater safety valve assembly is shown in figure 3–11. In this type of assembly, the unloading valve has no spring, and relies solely on pressure differential for its operation. Normally there is a static pressure above the disk of this valve, since some steam is allowed to pass through a small orifice in the skirt of the disk.

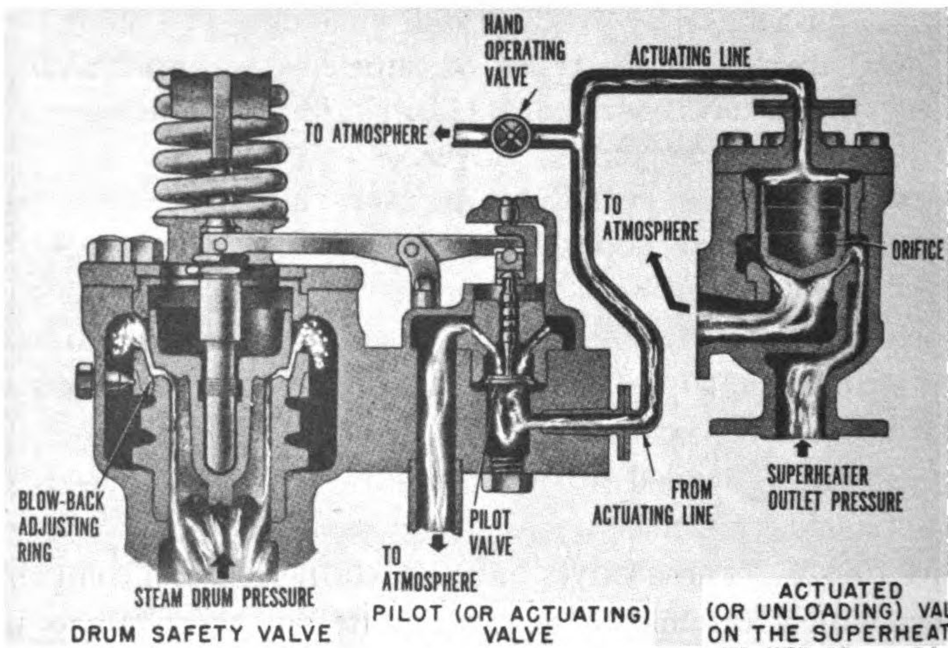


Figure 3–11.—Pressure pilot-operated superheater outlet safety valve assembly.

When the drum safety valve is opened by steam drum pressure, the pilot valve is also unseated. The opening of the pilot valve opens the actuating pipe line to the atmosphere; and the sudden relief of pressure above the disk causes the superheater unloading valve to lift wide open.

When the pressure in the steam drum falls to the reseating pressure of the drum valve, both the drum valve and

the pilot valve close. The closing of the pilot valve closes the actuating pipe line to the superheater unloading valve. The pressure above the disk of the unloading valve builds up again very quickly, and the disk is reseated sharply and cleanly.

Another type of pilot-operated superheater outlet safety valve assembly is similar to the one just described, except that it consists of only two valves: a pilot valve and a SPRING-LOADED superheater unloading valve. The pilot valve is a small safety valve with an additional outlet on one side. The pilot valve is connected by piping directly to an operating piston of the unloading valve. The unloading valve opens fully at almost the same moment as the pilot valve. If for any reason the pilot valve fails to open, the superheater valve will open at a slightly higher pressure, like any regular spring-loaded safety valve.

SOOT BLOWERS

Soot deposited on boiler tubes effectively insulates the tubes from furnace heat, and thus seriously reduces heat transfer. Soot blowers are installed adjacent to and between the boiler tubes, so that the boiler firesides may be cleared of soot deposits while the boiler is steaming. Several soot blowers are installed on each boiler. They are arranged so that operation in the proper sequence will sweep the soot progressively toward the uptakes. Figure 3–12 shows the general arrangement of soot blowers in an M-type boiler.

A soot blower is essentially a pipe with nozzle outlets. Superheated steam is admitted to the element and is discharged at high velocity through the nozzles, which direct the jets of steam so that they sweep over the tubes. The soot is thus loosened and carried out of the boiler by way of the uptakes and the stack.

One RETRACTABLE SINGLE-NOZZLE soot blower is installed in the roof of the superheater furnace of M-type boilers. Turning a handwheel advances the unit about 5 inches into

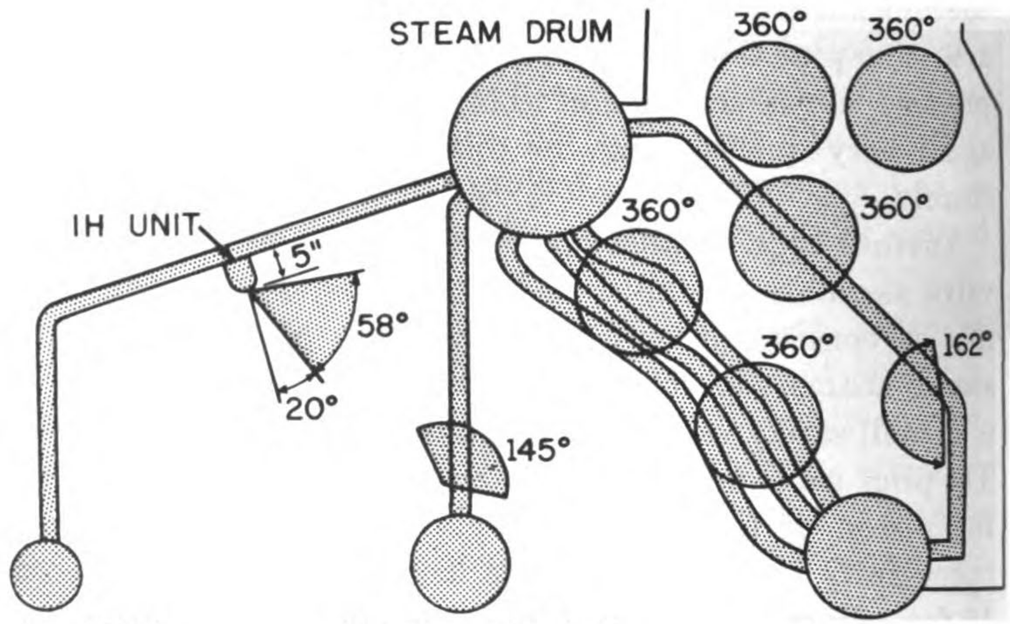


Figure 3–12.—Arrangement of soot blowers in M-type boiler.

the superheater furnace and causes an automatic admission of steam. The nozzle is then rotated by continued turning of the handwheel. Reversing the handwheel shuts off the steam and retracts the nozzle into a shroud between the inner and outer casings of the boiler. This retractable soot blower is usually referred to as the IH UNIT.

The other soot blowers are of the MULTI-NOZZLE type. In these blowers, a steam valve is actuated and the element is rotated by means of a crank or an endless chain. Steam is admitted from the soot blower head (shown in figure 3–13) into the element by means of a straight pipe which has small nozzles fitted along one side. The pipe can be rotated through 360°; on some blowers, however, the admission and cut-off of steam is so controlled that these blowers sweep during only a part of each revolution. Figure 3–12 shows the usual BLOWING ARCS for soot blowers on M-type boilers.

It should be noted that although the elements of multi-nozzle soot blowers are identical as to size and nozzle spacing,

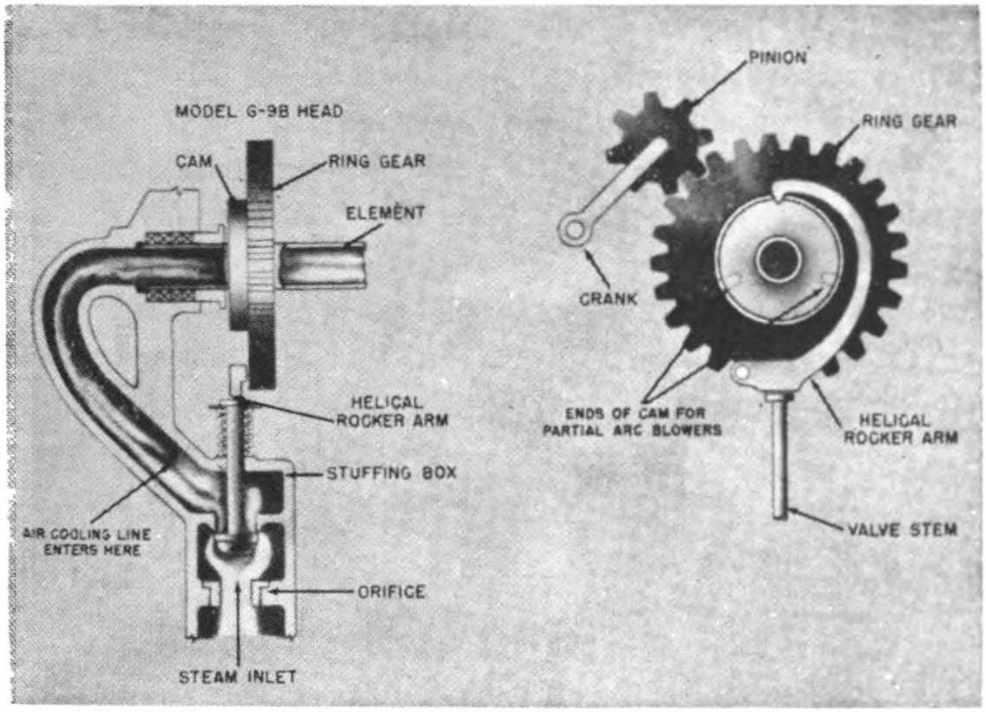


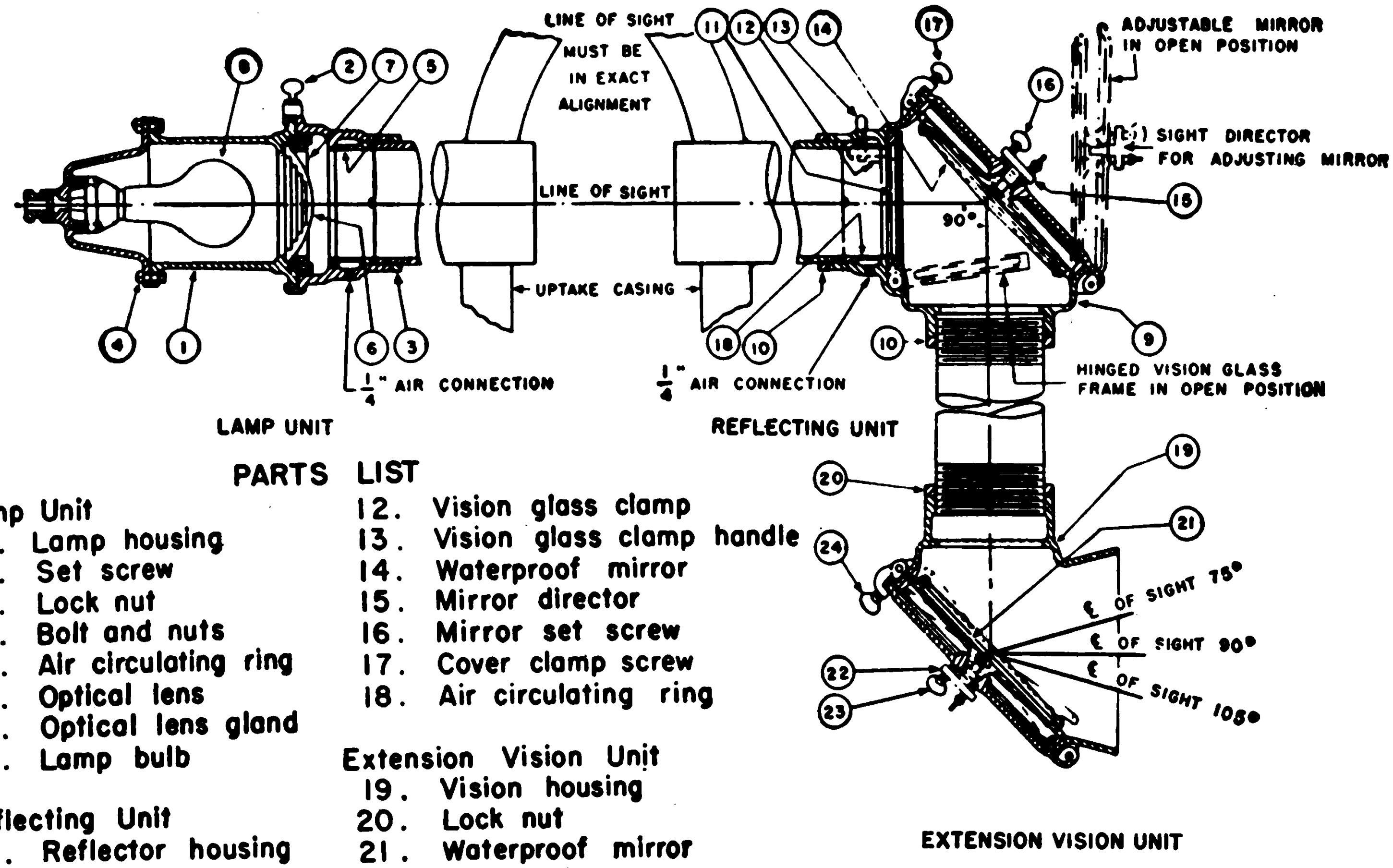
Figure 3–13.—Soot blower head.

they are NOT made of identical material, and are therefore NOT interchangeable. Each element is made of metal which is suitable for the temperatures to which it will be exposed; since the temperatures vary within the furnace, each soot blower element is designed for one location only.

SMOKE INDICATORS

Modern boilers are fitted with smoke indicators (sometimes called SMOKE PERISCOPES) which permit visual observation of the gases of combustion as they pass through the uptakes. Two smoke indicators are installed in the uptake of each two-furnace boiler; one permits observation of the gases coming from the saturated side, and the other of gases from the superheater side. Single-furnace boilers have only one smoke indicator.

Each smoke indicator consists of two units, one installed at the rear of the uptake, and the other at the front. The rear unit contains an electric light bulb and an optical lens; both are enclosed in a cylindrical casing which fits over a



PARTS LIST

Lamp Unit
1. Lamp housing
2. Set screw
3. Lock nut
4. Bolt and nuts
5. Air circulating ring
6. Optical lens
7. Optical lens gland
8. Lamp bulb

Reflecting Unit
9. Reflector housing
10. Lock nut
11. Vision glass
12. Vision glass clamp
13. Vision glass clamp handle
14. Waterproof mirror
15. Mirror director
16. Mirror set screw
17. Cover clamp screw
18. Air circulating ring

Extension Vision Unit
19. Vision housing
20. Lock nut
21. Waterproof mirror
22. Mirror director
23. Mirror set screw
24. Cover clamp screw

Figure 3–14.—Smoke indicator.

hole at the rear of the uptake. The front unit contains two mirrors; these are so arranged that the top mirror reflects the beam of light from the lamp down through a vertical tube to the second mirror, which then reflects the beam horizontally through an eyepiece. The front unit is enclosed in a cylindrical casing which fits over a hole in the front of the uptake. The two units (front and rear) are installed so that there is a direct line of sight between them. Thus by looking into the eyepiece, you can observe the smoke conditions in the uptake.

Figure 3–14 shows a smoke indicator in detail.

QUIZ

1. What is the difference between internal and external boiler fittings?
2. Why are the perforations on the internal feed pipe arranged so that the feed water will discharge upward?
3. In what type of boiler are swash plates most likely to be used?
4. What internal boiler fitting utilizes centrifugal force to separate steam and water?
5. Why does the dry pipe have perforations only along its upper surface?
6. Why are guarding valves installed in the boiler blow piping line?
7. What two devices are always used on modern high-pressure boilers to indicate the water level in the steam drum?
8. When must water gage glasses be blown down?
9. Which part of a combined feed stop and check valve unit must be installed nearest to the economizer inlet?
10. What three types of single-element automatic fed water regulators are now used in naval vessels?
11. What one factor controls the operation of all types of single-element automatic feed water regulators?
12. In the single-element thermal-hydraulic type of feed water regulator, what determines the position of the feed water regulating valve?

13. When an automatic feed water regulator is installed, where is the feed water regulating valve located?
14. What two factors control the operation of two-element automatic feed water regulators?
15. What terms are used to describe changes in the volume of water in the steam drum, when these changes occur without any corresponding changes in the weight of the water?
16. What advantage do multi-element feed water regulators have over single-element types?
17. Why does a boiler safety valve reseat at a lower pressure than that which caused it to lift originally?
18. How is blowdown adjustment made in the huddling chamber type of safety valve?
19. Why must superheater safety valves be set to lift at a lower pressure than drum safety valves?
20. What are the three main parts of a pressure pilot-operated superheater safety valve assembly?
21. What is the function of soot blowers?

CHAPTER 4

CONTROL INSTRUMENTS

A number of control instruments are required for the operation of boilers and associated fireroom machinery. As a Boilerman, you will be required to use such instruments as pressure gages, temperature gages, steam flow indicators and alarms, tachometers, and flue gas analyzers. Many of these instruments are classified as external boiler fittings.

In general, gages and instruments are designed to tell you HOW MUCH—how much pressure, how much heat, how much steam, how much speed. Control instruments tell you whether the machinery is operating properly, or whether some abnormal condition—excessive speed, high temperature, high pressure, low pressure—requires corrective action on your part. Control instruments also supply essential information for the hourly, daily, and weekly entries for station operating logs and the engineering log.

In this chapter we will take up the control instruments which are commonly found in the fireroom. In most cases, the information given here presupposes some knowledge of the basic operating principles of these devices. You may find it helpful to review the discussion of gages in *Fireman*, NavPers 10520-A, before going on to study this chapter.

PRESSURE GAGES

There are three basic types of pressure and vacuum gages used in naval engineering plants: (1) Bourdon-tube gages,

(2) diaphragm gages; and (3) manometers. When a single pressure gage is arranged to register both gage pressure and vacuum, it is known as a COMPOUND GAGE. When two pressure gage units are mounted in a single case, with each mechanism acting independently but with the pointers mounted on a common dial, the assembly is referred to as a DUPLEX GAGE. Duplex gages are used to give simultaneous indication of the pressures at two points in a system. For example, a duplex gage is often installed in the fuel oil system to indicate inlet and outlet pressures at the strainer; a large difference in the readings indicates that the fuel oil strainer basket is clogged.

BOURDON-TUBE GAGES are used chiefly for measuring high pressures. Gages of this type are often used for low pressure or vacuum measurement, but they are not as accurate in this use as diaphragm gages or manometers. A Bourdon-tube pressure gage is shown in figure 4–1. The gage movement is mounted on a stationary base or socket, so that movement of the case will not affect the accuracy of the gage.

DIAPHRAGM GAGES give sensitive and reliable indications of small pressure differences. In this type of gage, a diaphragm is connected to a pointer through a metal spring and a simple linkage system. One side of the diaphragm is exposed to the pressure being measured. As this pressure increases, the diaphragm is pushed upward against the action of the spring; and as the spring moves, the linkage system causes the pointer to move to a higher reading. Thus the reading on the scale is directly proportional to the amount of pressure exerted on the diaphragm. Diaphragm air-pressure gages are often used to measure the air pressure in the space between the inner and the outer boiler casings.

The simplest, most accurate, and least expensive instrument for measuring low pressure or low-pressure differentials is the LIQUID MANOMETER. A manometer is a U-shaped tube which is partially filled with a liquid of known density, such as water, oil, or mercury. The difference in pressure at the two ends of the U-tube is shown by the

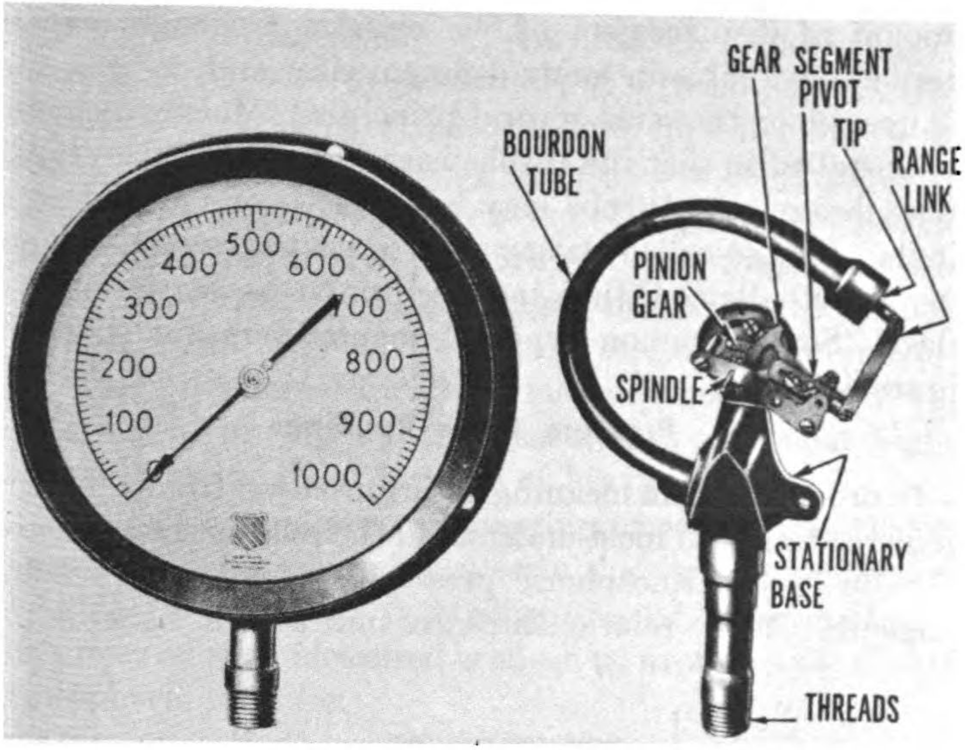


Figure 4–1.—Bourdon-tube type pressure gage.

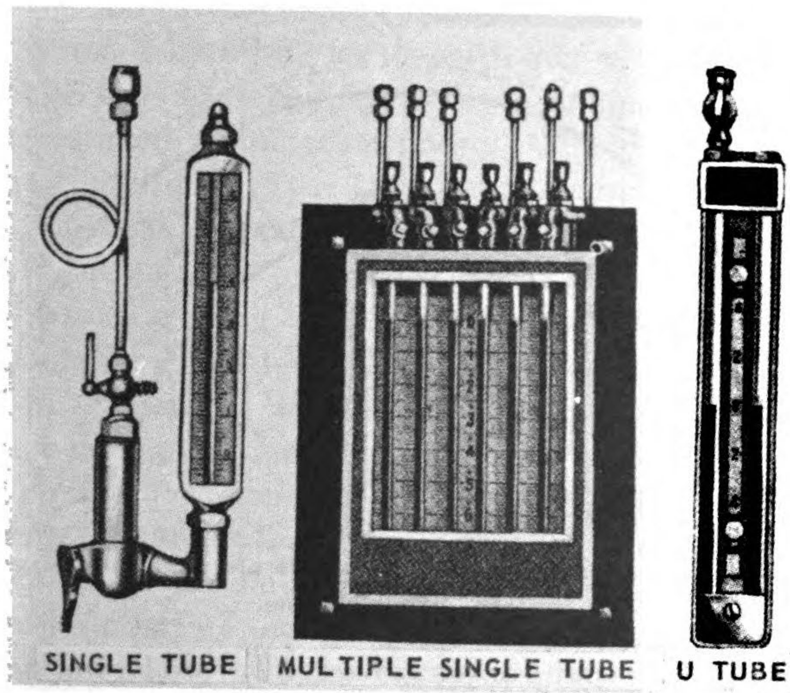


Figure 4–2.—Types of manometers.

amount of displacement of the liquid. Although manometers are available in many different sizes and designs, they all operate on the same general principle. Most manometers are installed so that the U-tube is easily recognizable; but in some designs the U-tube may be inverted or inclined at an angle. The so-called SINGLE-TUBE or STRAIGHT-TUBE manometer is actually a U-tube in which only one leg is made of glass. Some common types of manometers are shown in figure 4–2.

Pressure Gage Readings

In order to obtain meaningful information from a pressure gage reading, you must understand the relationships between gage pressure, atmospheric pressure, vacuum, and absolute pressure. These relationships are indicated in figure 4–3.

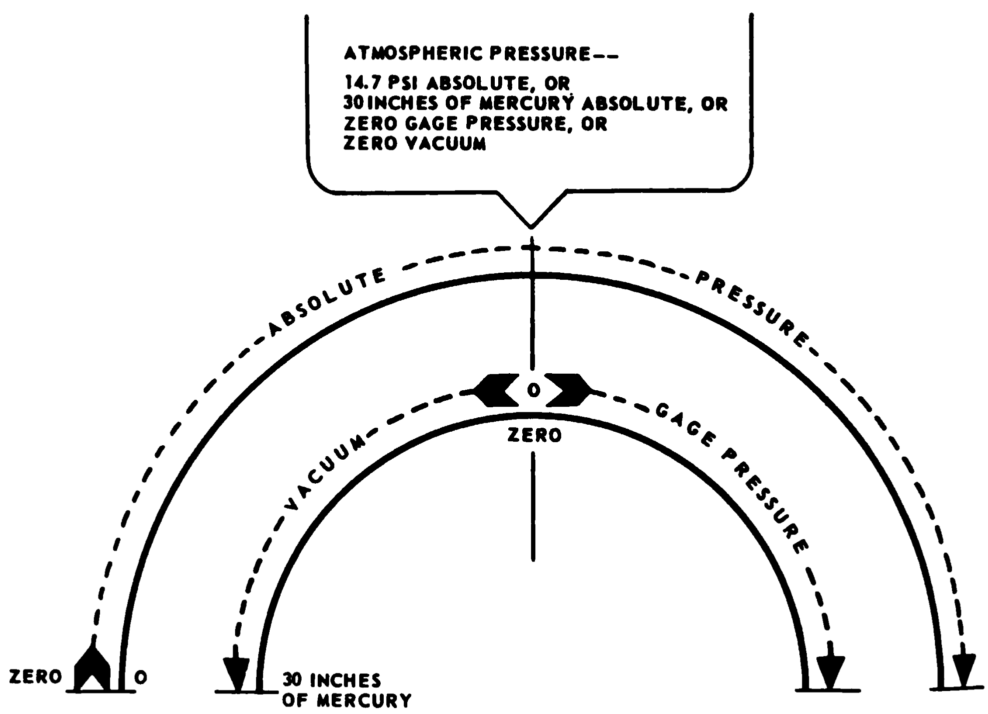


Figure 4–3.—Relationships between vacuum, gage pressure, absolute pressure, and atmospheric pressure.

GAGE PRESSURE is the pressure actually shown on the dial of a gage which registers pressures at or above atmospheric pressure. Gage pressure is usually shown in pounds per square inch (psi); but it may be shown in inches of water,

mercury, or other liquid. A reading of 1 inch of water means that the exerted pressure is able to support a column of water 1 inch high, or that a column of water in a U-tube would be displaced 1 inch by the pressure being measured. Similarly, a gage pressure reading of 12 inches of mercury means that the measured pressure is able to support a column of mercury 12 inches high. Gages are calibrated in inches of water when they are to be used for the measurement of very low pressures. Inches of mercury may be used when the range of pressures to be measured is somewhat higher, since mercury is about 14 times as heavy as water.

Note that a gage pressure reading of zero means that the pressure being measured is exactly the same as the existing atmospheric pressure. A gage reading of 50 psi means that the pressure being measured is 50 psi IN EXCESS OF the existing atmospheric pressure.

ATMOSPHERIC PRESSURE, or the pressure exerted by the weight of the air in the atmosphere, is measured with a BAROMETER. A barometer is similar to a manometer, except that the indicating tube is sealed at the top. A barometer may be made by filling a tube with mercury and then inverting it so that the open end rests in a container of mercury which is open to the atmosphere. The absence of pressure at the closed end of the tube permits atmospheric pressure, acting upon the surface of the mercury in the open container, to hold the mercury in the tube at a height which corresponds to the pressure being exerted.

Normally, at sea level, atmospheric pressure will hold the column of mercury at a height of approximately 30 inches. Since a column of mercury 1 inch high exerts a pressure of 0.49 pounds per square inch, a 30-inch column of mercury exerts a pressure which is equal to 30 x 0.49, or 14.7 pounds per square inch. Thus we can say that atmospheric pressure at sea level is 14.7 psi. Notice, however, that this figure of 14.7 psi is the STANDARD for atmospheric pressure. Since fluctuations from this standard are shown on the barometer, the term BAROMETRIC PRESSURE is used to describe the atmospheric pressure which exists at any given moment. As a rule,

you can use the term ATMOSPHERIC PRESSURE and the value 14.7 psi in place of the actual barometeric pressure; but there may be times when it will be important to know the ACTUAL (barometric) pressure, in order to make precise measurements of gage pressure or vacuum.

A space in which the pressure is LESS than atmospheric pressure is said to be under VACUUM. The amount of vacuum is expressed in terms of the difference between the pressure in the space and the existing atmospheric pressure. Vacuum is measured in inches of mercury—that is, the number of inches a column of mercury in a U-tube would be displaced by a pressure equal to the DIFFERENCE between the pressure in the vacuum space and the existing atmospheric pressure.

Vacuum gage scales are marked from 0 to 30. When a vacuum gage reads zero, the pressure in the space is the same as the existing atmospheric pressure—or, in other words, there is no vacuum. A vacuum gage reading of 30 inches of mercury would indicate a nearly perfect vacuum. In actual practice, it is impossible to obtain a perfect vacuum; and the highest vacuum gage readings are seldom over 29 inches of mercury.

ABSOLUTE PRESSURE is atmospheric pressure PLUS gage pressure, or atmospheric pressure MINUS vacuum. For example, if gage pressure is 300 psi, absolute pressure is 314.7 psi; or if the measured vacuum is 10 inches of mercury, absolute pressure is approximately 20 inches of mercury. It is important to note that the amount of PRESSURE in a space under vacuum can be expressed only in terms of absolute pressure.

Sometimes it is necessary to convert a reading from inches of mercury to pounds per square inch. Figure 4–3 gives you all the information you need to make this conversion. Since atmospheric pressure is equal to 14.7 psi OR to 30 inches of mercury, it is easy to see that 1 inch of mercury is equal to 14.7 psi divided by 30, or 0.49 psi. Now convert your gage reading to absolute pressure (in inches of mercury) and then multiply this figure by 0.49 psi. For example, to convert a

vacuum gage reading of 14 inches of mercury to psi, you would:

1. Convert 14 inches of mercury VACUUM to ABSOLUTE PRESSURE. Absolute pressure is atmospheric pressure MINUS vacuum, or 30 inches $-$ 14 inches $=$ 16 inches.
2. Multiply the absolute pressure in inches of mercury by 0.49. Since 1 inch of mercury is equal to 0.49 psi, 16 inches of mercury is equal to 16×0.49 psi, or 7.8 psi (about 8 psi). Don't forget that this answer is in terms of ABSOLUTE PRESSURE.

As you can see, it is also easy to convert psi to inches of mercury. Since atmospheric pressure is equal to 14.7 psi OR to 30 inches of mercury, 1 psi is equal to 30 inches of mercury divided by 14.7, or 2.04 inches of mercury. For example, 10 psi absolute is equal to 10×2.04 inches of mercury, or 20.4 inches of mercury absolute.

In order to interpret the reading on a pressure gage, you must know the LOCATION of the gage in relation to the line in which the pressure is being measured. As a general rule, pressure gage connections are led from the top of the pressure line. Occasionally, however, it is necessary to locate a pressure gage at some distance BELOW the pipe; and in such a case the reading on the gage will indicate the pressure being measured PLUS the pressure exerted by the weight of the column of liquid above the gage. The required correction should be made in calibration of the gage; but if it has not been made in calibration, it must be made in the interpretation of the gage reading.

Correction for a head of liquid should be made as follows:

1. Measure the verticle distance from the center of the gage to the line in which the pressure is being measured.
2. For each foot of the distance measured, subtract from the gage reading the weight of a column of liquid 1 foot high and 1 inch square in cross section. If you are measuring pressure on a steam or water line, you must correct for a head of water. Since a column of water 1 foot high and 1 inch square in cross section weighs

0.433 pounds, you subtract 0.433 psi from the gage reading for each foot of drop. (CAUTION: The weight of each liquid is different, and must be determined before you can make this correction.)

As an example of how to correct a pressure gage reading for a head of water, let's assume that a steam pressure gage is connected 10 feet below the steam line. The steam cools and condenses in the gage connection line, thus filling the connection line with water. The uncorrected gage reading is 250 psi. Multiply 0.433 psi by 10, and then subtract the resulting figure from 250 psi:

(1) $0.433 \text{ psi} \times 10 = 4.33 \text{ psi}$

(2) $250 \text{ psi} - 4.33 \text{ psi} = 245.67 \text{ psi}$

Thus the true pressure on the steam line is 245.67, or approximately 246 psi.

It is sometimes necessary to connect a water pressure gage at some distance ABOVE the point at which the pressure is being measured; and in such a case the reading on the gage will show the pressure being measured MINUS the pressure required to support the column of water up to the gage. To correct the reading, you must ADD the weight of the column of water—that is, you must add 0.433 psi to the gage reading for each foot of rise.

Let's assume, for example, that a water pressure gage is connected 5 feet above the point at which the pressure is being measured. The gage reading is 30 psi. To obtain the actual pressure at the point of measurement, you must add 5×0.433 psi or 2.17 psi, to the gage reading. Thus the actual pressure is 32.17 psi.

Pressure Gage Installation

Bourdon-tube pressure gages used for steam service are always installed in such a way that the steam cannot actually enter the gage. This type of installation is necessary for the protection of the Bourdon tube, which cannot withstand very high temperatures. An exposed (uninsulated) coil is provided in the line leading to the gage, and the steam con-

denses into water in this exposed coil. Thus there is always a condensate seal between the gage and the steam line. Sometimes the condensate seal is lost when repairs are made to the gage or to the gage line; in this event, the loop must always be filled with water before the gage is subjected to steam line pressure.

As mentioned before, pressure gage connections are led from the top of the pressure line whenever possible. Boiler steam pressure gages are connected to the highest part of the drum. Vacuum gages are connected to the top of condensers.

With few exceptions, pressure gage cases are mounted on flat-surfaced gage boards in such a way as to minimize vibration of the gages. The gage boards are not attached directly to operating machinery or to anything which is likely to vibrate. A resilient rubber washer is used on each securing bolt between the gage case and the gage board.

Pressure gage connection lines must always be supported so that no strain can be transmitted to the gage mechanism. If the gage connection line is subject to excessive vibration, a flexible connector is used between the vibrating line and the gage board. Precautions must always be taken to avoid leaky joints in gage connection lines. If there is a leak in a steam pressure gage connection, the condensate seal may be lost and the gage reading will not be accurate. Vacuum gage connection line joints must be kept tight in order to prevent the entrance of air.

Pressure Gage Testing

Bourdon-tube pressure gages must be tested once every six months, at least, and oftener if inaccuracy is suspected. Vacuum gages are tested at least once every nine months, during tender or naval shipyard overhaul.

Pressure gages are tested either by comparison with other gages or by means of a dead-weight testing apparatus. The simplest way to make a spot-check on a gage is to compare its readings with those of other gages installed in the same line.

Some ships are furnished with a PNEUMATIC COMPARATOR for comparing readings on the service gage with readings on the test gage, when both are subjected to the same pressure. The comparator is a portable, self-contained testing unit. Testing pressures are supplied by a built-in, rechargeable, high-capacity gas cylinder; compressed air or any inert gas may be used. (Oxygen must NEVER be used.) The comparator has three test gages, each of which has an outlet for connecting the service gage. Each test gage has a different range. In order to be tested on the comparator, a mounted gage must be equipped with a permanently installed plugged T-connection, and a cock or valve which can be used to isolate the gage from the line pressure. The main advantage of the pneumatic comparator is that it can be used to check the accuracy of service gages without removing them from their gage board and without disturbing the existing line connections.

The DEAD-WEIGHT PRESSURE GAGE TESTING APPARATUS shown in figure 4–4 is available on most ships. In this type of testing device, the gage is subjected to hydrostatic pressure. A

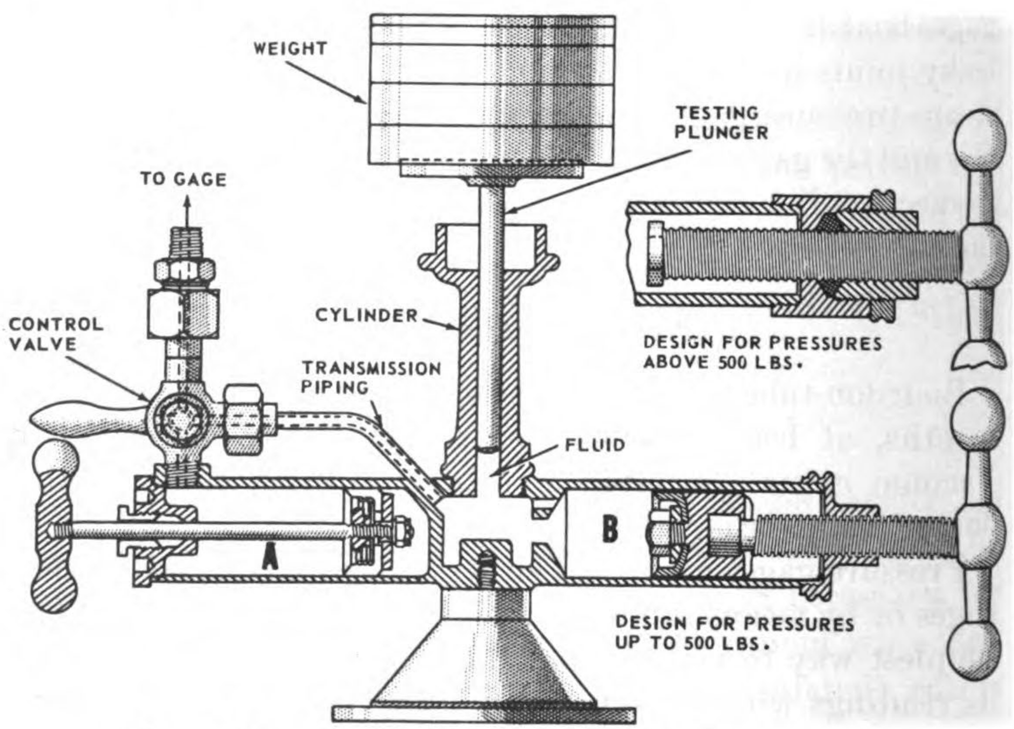


Figure 4–4.—Dead-weight pressure gage testing apparatus.

plunger of known area is accurately fitted into a vertical cylinder which contains a water-base hydraulic fluid. (Mineral oil or other petroleum products must NEVER be used.) Weights are applied to the plunger, and the pressure is transmitted to the fluid and then to the gage by way of transmission piping and a control valve. The plunger itself exerts a known pressure (usually 5 or 10 psi); and additional weights in appropriate sizes are provided. Normally, 5, 10, 20, and 100 psi weights are available.

In figure 4–4, you will notice, there are two horizontal cylinders, in addition to the main vertical cylinder. Cylinder A and its plunger are used to pump the hydraulic fluid into the instrument, in the initial filling. Cylinder B is an auxiliary cylinder which connects with the main (vertical) cylinder. The plunger in cylinder B is used to exert a sufficient force on the fluid so that the testing plunger maintains the weight platform in position about 2 inches above the top of the vertical cylinder. At the beginning of a test, the plunger in cylinder B should be screwed out as far as it will go, so that the auxiliary cylinder (as well as the main cylinder) will be filled with fluid. If the weighted test plunger is pushed too far down, at any time during the test, the plunger in cylinder B should be screwed in as far as necessary to force the test plunger up so that it will have freedom of movement.

When a pressure gage is being tested in this type of testing device, the gage is connected to the apparatus. If necessary, the tester is filled with the proper water-base hydraulic fluid. (Some testers of this type are designed to be kept full of fluid at all times, but others require filling before each use.) The tester is then leveled. Weights are added to the plunger, as required, and the pressure gage readings are checked for accuracy. The plunger should be gently rotated as each weight is added, in order to ensure its freedom of movement. If the gage reading increases by the proper amount as each weight is added, and if the gage reading is equal to the pressure represented by the total weight added, the gage is in adjustment.

Gages should be as accurate as possible. On acceptance tests, the maximum allowable errors for various types of gages are as follows:

PRESSURE GAGES.—In the part of the scale which is between 33⅓ and 66⅔ percent of the maximum scale reading, errors must not exceed ½ of 1 percent of the maximum reading to which the scale is graduated. The error in reading at any other point above 5 percent of the maximum reading on the scale must not exceed 1½ percent of the maximum reading to which the scale is graduated.

VACUUM GAGES.—The error in reading must not exceed ¼ inch between 5 and 30 inches of mercury.

COMPOUND GAGES.—On the pressure side, errors of reading must not exceed 1½ percent of the maximum reading to which the scale is graduated. On the vacuum side of a 30-inch to 30-psi compound gage, errors in reading must not exceed ½ inch between 5 and 30 inches of mercury. On the vacuum side of a 30-inch to 100-psi compound gage, errors in reading must not exceed 1½ inches between 5 and 30 inches of mercury.

When a Bourdon-tube pressure gage is found to be inaccurate, the following adjustments may be made:

1. If the pointer travels too far or not far enough, as each weight is applied, the fault should be corrected by changing the ratio of movement between the Bourdon tube and the pointer. The movement of the pointer is controlled by the movement of the sector gear, which meshes with a pinion on the pointer spindle. Lengthening the distance between the pointer spindle and the link connection to the sector gear will reduce the amount of travel of the pointer; shortening the distance will increase the amount of travel.
2. If the amount of increase is correct, as each weight is added, but the total reading is wrong, the pointer must be reset. Gages of recent design have a countersunk split head screw in the dial for setting the pointer. In older types of gages, the pointer must be pulled and reset.

3. If the gage cannot be made to read correctly over the entire scale, it should be adjusted so that the reading is correct at the WORKING PRESSURE. A table or curve should then be made which will show the corrections to be applied for other readings.

A pointer puller is supplied with the gage testing apparatus, and should be used whenever it is necessary to remove the pointer in order to get at the interior of the gage.

Diaphragm air-pressure gages should be checked frequently to be sure that the zero adjustment is correct. Each gage has a three-way cock which can be turned to shut off the gage without disconnecting the gage piping. When the handle of the three-way cock is at right angles to the valve body, the gage unit is open to the outside air pressure and the reading on the scale should be zero. When the handle of the three-way cock is parallel to the valve body, the gage unit is open to the pressure in the line.

A zero adjusting screw is provided either below the gage or on one side of the gage. Zero adjustment is made by turning this screw in or out, as required, to bring the pointer to zero. After zero adjustment has been made the cock handle is turned back again so that it is parallel with the valve body, and the gage is thus restored to service.

Care and Maintenance of Pressure Gages

Pressure gages are precision instruments which require a certain amount of care. If it is necessary to renew any part of a gage, the mechanism must be handled carefully so that none of the elements will be bent or distorted. Spare gages must be kept dry, and must be stowed in a place where they will not be subjected to severe shocks.

Occasionally, it is necessary to replace the diaphragm in a diaphragm air-pressure gage. To do this, first disconnect the pressure line below the unit. Remove the outside zero adjustment screw and the three-way cock (with its coupling), and remove the unit from its case.

Disassemble the unit by compressing the small spring on top of the calibrating spring; this will loosen the retaining pin. Remove the stem which holds the calibrating spring, and remove the ten screws around the edge of the diaphragm housing. The old diaphragm can then be lifted out.

Clean both surfaces of the housing. Apply a small amount of gasket cement to the edge of the lower housing, and immediately place the new diaphragm-gasket assembly over the edge of the lower housing. Replace the top housing. Tighten the screws; be careful to draw them up uniformly so as to make a tight joint. Replace the calibrating spring stem, compress the spring, and insert the retaining pin in the stem. Then replace the unit in the case, and the gage is ready for service.

Special Precautions

In the past few years, there have been several serious shipboard explosions originating in hydro-pneumatic machinery and in high-pressure air, oxygen, and other gas systems. It is believed that some of these explosions may have been caused by a "Diesel effect" occurring in the Bourdon tubes of pressure gages when the gages were suddenly opened to high pressures (600 psi and above).

As you may remember from the *Fireman* course, a Diesel engine operates by taking in air, compressing it, and then injecting fuel into the cylinders, where it is ignited by the heat of compression. This same effect may occur in the Bourdon tube of a pressure gage, if even a very small amount of "fuel"—a smear of oil, a single cotton thread—is present to be ignited by the heat of compression. In order to minimize the danger of explosion, the following precautions MUST be observed:

1. When a Bourdon-tube type pressure gage is removed from machinery for recalibration, the internal surface of the Bourdon tube must be thoroughly cleaned with carbon tetrachloride, trichloroethylene, or some other approved solvent, to remove any oil or grease which may

have gotten into the tube. The tube should be exposed to circulating air until it is entirely dry.

2. Nonflammable water-base hydraulic fluid must be used in the dead-weight pressure gage testing apparatus. NEVER USE MINERAL OIL OR OTHER PETROLEUM PRODUCTS WHEN TESTING HIGH-PRESSURE GAGES!

TEMPERATURE GAGES

Temperature measurement is essential to the proper operation of an engineering plant. In performing your duties as a Boilerman, you will be required to observe and record the temperature of feed water, fuel oil, lubricating oil, saturated steam, superheated steam, and various other liquids and gases.

The basic principles of temperature measurement are discussed in *Fireman*, NavPers 10520–A. As you probably remember, the direct-reading liquid-in-glass thermometer and the distant-reading Bourdon-tube thermometer are the types of temperature gages most commonly used on board ship.

The LIQUID-IN-GLASS THERMOMETER contains mercury, alcohol, benzine, or some other liquid suitable for the temperature range involved. Most of the liquid-in-glass thermometers that you will be using contain mercury. When the bulb is exposed to the temperature being measured, the mercury expands and rises in the capillary tube (glass stem). The reading is then taken by noting the position of the meniscus (the curved upper surface of the mercury) in the stem. Calibration marks may be etched on the glass stem, or they may be carried on a separate strip of material which is placed behind the stem.

Liquid-in-glass thermometers are made in various designs. The stem may be straight, or it may be bent to a required angle. Many thermometers used in the fireroom are of the angle-stem type, since they must be fitted into small spaces. Glass thermometers may be armored, or may be partially enclosed by a metal case, if such protection is necessary.

DISTANT-READING BOURDON-TUBE THERMOMETERS are used when the indicating part of the instrument must be placed

some distance away from the point where the temperature is being measured. A Bourdon-tube thermometer consists essentially of three parts: a bulb, an armored capillary tube, and a Bourdon-tube type pressure gage. All three elements are filled with mercury. When the bulb is heated, the mercury expands and causes pressure to be communicated by way of the capillary tube to the Bourdon tube. The Bourdon tube tends to straighten out as pressure is applied, and this movement is transmitted through linkages and gears to a pointer. The pointer moves over a scale which is calibrated in degrees, so that the temperature may be read directly from it. A Bourdon-tube distant-reading thermometer is shown in figure 4–5.

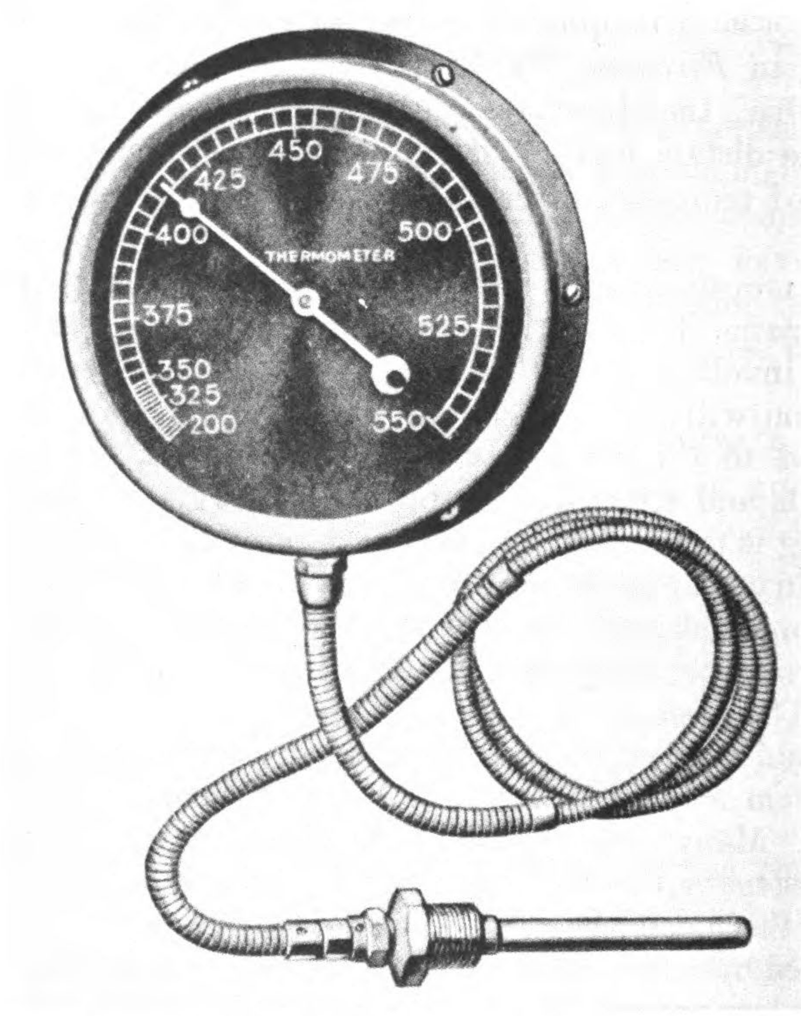


Figure 4–5.—Bourdon-tube distant-reading thermometer.

Bare Bulb Thermometers

Both direct-reading (glass stem) and distant-reading (Bourdon-tube) thermometers used for superheated steam service on superheat control boilers are usually of the bare bulb type—that is, the bulb is in direct contact with the steam. Bare bulb thermometers must NEVER be removed for replacement or servicing while the boiler is steaming under pressure.

Thermometer Wells

Most of the thermometers used in the fireroom are of the well, or separable socket, type—that is, the bulb must be inserted into a well or socket in the line where the temperature is being measured. These thermometers are not designed to be used as bare bulb thermometers; they should always be used in the well or socket.

In order to decrease the excessive time lag which is likely to occur with this type of thermometer, the space around the bulb in the well should be filled with a mixture of heavy mineral oil and graphite, for temperatures below 300° F; or with graphite alone, for temperatures above 300° F.

Testing and Calibration

Thermometers used on board ship are ordinarily tested and calibrated at a naval shipyard or tender. When inaccuracies are suspected, however, thermometers should be tested by comparing them with others of known accuracy, and, if necessary, by immersing them in substances of known temperature. If the temperature range of the thermometer is appropriate, the instrument should be tested at the freezing and boiling points of water. At atmospheric pressure, water freezes at 32° F and boils at 212° F. A mixture at 32° F can be prepared by placing small pieces of pure ice in a small amount of distilled water.

In some instances it may be necessary for you to calibrate the two bare bulb thermometers (one direct-reading and one distant-reading) which are installed at the superheater out-

let. If the readings of the two thermometers differ by more than 10° F, calibration should be done by the following method:

1. Remove the glass stem thermometer at the first opportunity. Remember, the thermometer must NEVER be removed when the boiler is under pressure.
2. Immerse the bulb of the glass stem thermometer in boiling water at atmospheric pressure (212° F) and note any error in the reading.
3. Immerse the bulb of the glass stem thermometer in a pot of molten zinc. As the zinc cools, the temperature will drop to 787° F, where it will remain while the zinc is hardening. The thermometer bulb should be agitated in the molten zinc while this test is being made.
4. Average the two errors found by these two tests, to get the approximate average error of the thermometer. Shift the thermometer scale up or down as required to correct for this error.
5. Repeat the tests again, as a check on the accuracy of the adjustment.
6. When the glass stem thermometer appears to be correctly calibrated, reinstall it on the boiler. Under steady steaming conditions and at approximately normal operating temperature, compare the readings of the glass stem thermometer and the distant-reading Bourdon-tube thermometer. The distant-reading thermometer may now be adjusted so that it reads the same as the glass stem thermometer which you have just calibrated. Adjustment of the distant-reading thermometer is made by rotating the dial or by resetting the dial pointer until it is in agreement with the direct-reading glass stem thermometer.

Precautions

Thermometers are precision instruments, and must be handled with care. The glass stem type of thermometer, in particular, is easily broken. All thermometers should be installed in such a way that they will not be exposed to undue

shock or vibration. Spare thermometers must be carefully stowed.

A thermometer should never be exposed to a temperature which is above the limit of its graduation. Exposure to excessive temperature would cause the mercury to expand enough to fill the entire space within the bulb and stem; and the pressure would cause the bulb to break. Thermometers with a scale range up to 750° F may be subjected continuously to any temperature on the scale, without danger to the instruments. Thermometers which are graduated up to 900° F may be occasionally exposed to the maximum temperature, but they should not be used continuously at temperatures above 850° F. Thermometers which are graduated up to 1,000° F may at times be used at the upper range limit, but the limit for continuous use is 900° F.

If the mercury column within a glass tube becomes broken, you may be able to join it by shaking down the thermometer. Hold the instrument at the upper end and swing your arm downward. Repeat the procedure if necessary. If the mercury column is still separated, heat the bulb carefully until the expansion of the mercury brings the two parts of the column together again. Do not attempt to join the sections of a broken mercury column by tapping or jarring the thermometer.

Damage that causes loss of mercury can be repaired only by the manufacturer. This fact is probably obvious enough in the case of a glass stem thermometer, but may not be so clear in the case of a Bourdon-tube distant-reading type. The capillary tube, which may be as much as 25 feet in length, is filled with mercury, as is the bulb and the Bourdon tube. Since the capillary tube is armored, however, it looks from the outside somewhat like an electric cable. In some instances, men working with this type of thermometer have tried to shorten or repair the tube by cutting it and attempting to splice it as though it were an electric cable. If the tube is cut, however, mercury will be lost; and the instrument will be useless until repaired by the manufacturer.

SUPERHEATER TEMPERATURE ALARM

Superheater temperature alarms are installed on most boilers, to warn operating personnel when the temperature in the superheater reaches the upper limit of safety. The alarm, which is shown in figure 4–6, works on the Bourdon

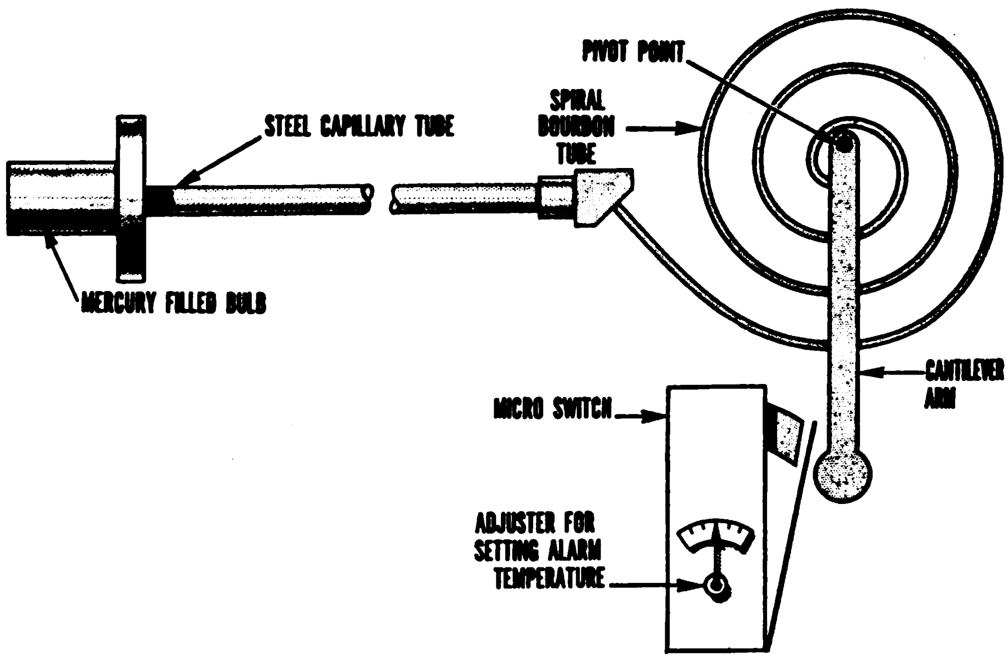


Figure 4–6.—Superheater temperature alarm.

tube principle. The bulb, the capillary tube, and the spiral-shaped Bourdon tube are filled with mercury. As the temperature rises, the mercury expands, causing the Bourdon tube to move so that an attached cantilever arm is moved toward an electric microswitch. When the temperature reaches a predetermined point, the cantilever arm closes the microswitch. A warning light and a warning howler are thus actuated; and, in some installations, the quick-closing fuel oil supply valves are automatically closed.

After the superheater temperature has dropped 10 to 15 degrees below the alarm temperature, the alarm shuts off. A screw adjustment is provided, so that the temperature at which the alarm functions may be raised or lowered.

A basic problem associated with measuring superheat temperatures arises from the fact that the measuring devices

depend, for correct operation, upon a reasonably good flow of steam through the superheater. If the flow of steam is reduced or entirely stopped, the temperature reading at the superheater outlet will NOT give a true indication of the temperature within the superheater. Under these conditions, neither the superheater outlet thermometers nor the superheater temperature alarm can be depended upon to give adequate warning of dangerous temperatures in the superheater.

REMOTE PRESSURE DIFFERENTIAL INDICATORS

Remote pressure differential indicators are used in the fireroom for two different purposes: (1) to show the rate of steam flow through the superheater; and (2) to show the water level in the steam drum. In each case, the indicator is actuated by a relatively small DIFFERENCE between two pressures; and the pressure differential is transmitted to an appropriately calibrated dial. The dial is usually located at the front of the boiler, at about eye level, so that it may be easily read by operating personnel. Remote pressure differential indicators are usually connected to some type of warning signal.

Superheater Steam Flow Indicators

The remote pressure differential indicators used to show the rate of steam flow through the superheater are called SUPERHEATER STEAM FLOW INDICATORS or SUPERHEATER PROTECTION DEVICES. They measure the difference in steam pressure between the superheater inlet and the superheater outlet. Since the pressure drop across the superheater is proportional to the rate of steam flow through the superheater, it is possible to use the pressure drop as an indication of the rate of steam flow.

Superheater steam flow indicators are usually calibrated in inches of water, rather than in psi, because the pressure difference which they measure is relatively small.

Two types of superheater steam flow indicators are used on naval vessels. Although both types respond to the pres-

sure differential between the superheater inlet and the superheater outlet, they differ in the mechanism by which this difference is transmitted to an indicating dial.

The BAILEY LOW FLOW SUPERHEATER PROTECTION DEVICE is an electronic telemetering system. It consists of three basic elements: (1) a transmitter, which is actuated by differential pressure; (2) an indicating receiver, which resembles a voltmeter; and (3) a vacuum tube amplifier and motor control unit, which balances the circuit and prevents the supply voltage from affecting the reading on the gage.

The difference between superheater inlet pressure and superheater outlet pressure is measured in terms of the difference in pressure on two columns of water. Two reservoirs are located above the transmitter. Steam from the superheater inlet is piped to one reservoir, and steam from the superheater outlet is piped to the other. A constant water level is maintained in each reservoir. An exposed pipe leads from the inlet reservoir to the high-pressure connection on one side of the transmitter; another exposed pipe leads from the outlet reservoir to the low-pressure connection on the other side of the transmitter. The reservoirs, the connecting piping, and the transmitter are filled with water before the equipment is put into operation.

In the transmitter, the water from the inlet (high pressure) reservoir applies pressure against the outside of a bellows, while water from the outlet (low pressure) reservoir applies pressure simultaneously on the inside of the bellows. The movement of the bellows is transmitted by a rigid vertical rod to the movable iron core of a transformer which is located just above the transmitter cylinder.

The pressure drop across the superheater, as represented by the position of the iron core, is transmitted electrically to the indicating receiver as a ratio of the output voltages from the two secondary windings of the transmitter. A reversing motor positions the indicating pointer, through a linkage, and also operates a contact which, at a specified setting, closes an electrical circuit by which the warning sign "SECURE SUPERHEATER BURNERS" is illuminated.

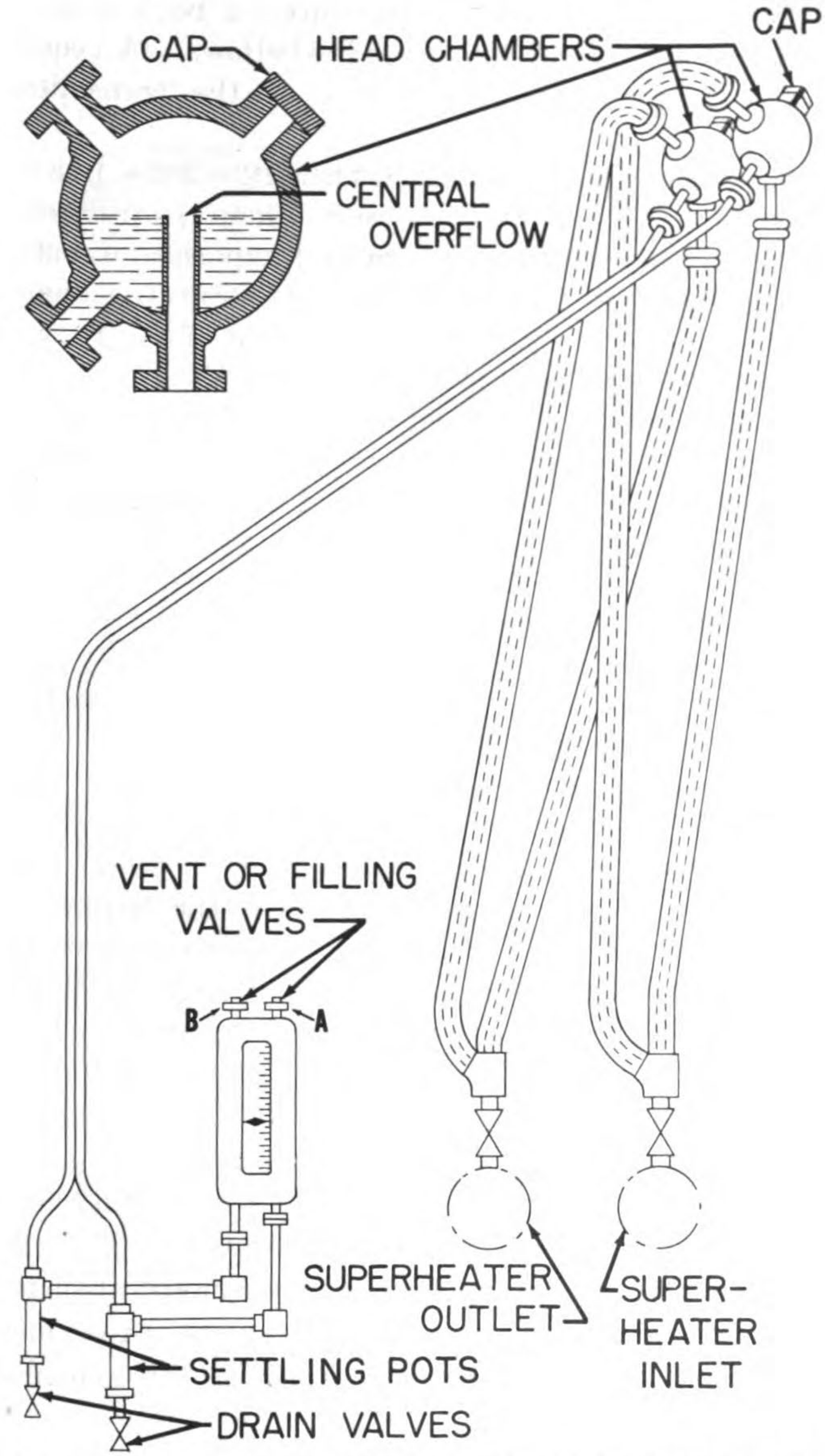


Figure 4–7.—Yarway remote pressure differential indicator (general arrangement).

Caution: When cutting in the Bailey low flow protection device, be sure to equalize the pressure on both sides of the bellows, so as to avoid damaging the bellows. An equalizing valve is provided on the side of the transmitter cylinder.

The Yarway superheater steam flow indicator, like the Bailey low flow protection device, responds to the difference between superheater inlet pressure and superheater outlet pressure, as these two pressures act upon separate columns or heads of water. The general arrangement of the Yarway indicator is shown in figure 4–7.

A constant water level is maintained in the two reservoirs, or head chambers. Both head chambers are in one casting, but the upper head chamber is located 2 inches above the lower head chamber in order to provide a slight constant pressure differential which serves to stabilize the zero reading. Steam from the superheater inlet is led to the upper head chamber, and steam from the superheater outlet is led to the lower head chamber. Exposed piping connects each head chamber with the indicating unit.

The interior of the indicating unit is shown in cross section in figure 4–8 (plan view), figure 4–9 (side view), and figure 4–10 (front view). Notice that the water from the upper head chamber enters on one side of the diaphragm, and the water from the lower head chamber enters on the other side. The pressure from the upper head chamber is greater than that from the lower head chamber, and therefore the diaphragm is moved. The diaphragm is connected by a pin linkage to a deflection plate which moves in sensitive response to the movement of the diaphragm.

A permanent horse-shoe magnet is rigidly mounted to that side of the deflection plate which is free to move. The poles of the magnet straddle a tubular well in which a spiral-shaped strip armature is mounted on jeweled bearings. A counterbalanced pointer is attached to the end of the armature mounting shaft.

When the deflection plate moves in response to variations in pressure, the magnet is made to move along the axis of

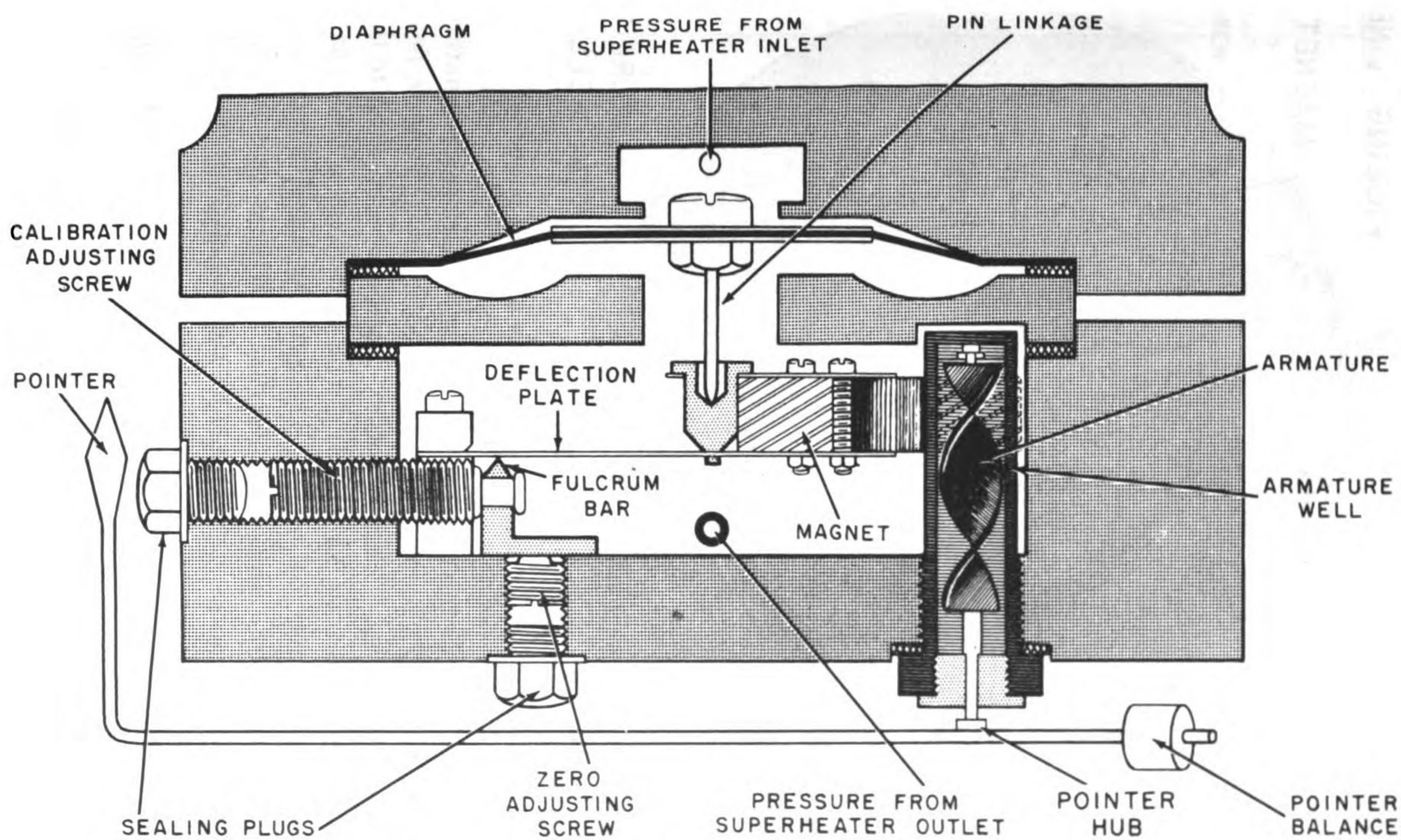


Figure 4–8.—Cross section of indicator unit (plan view).

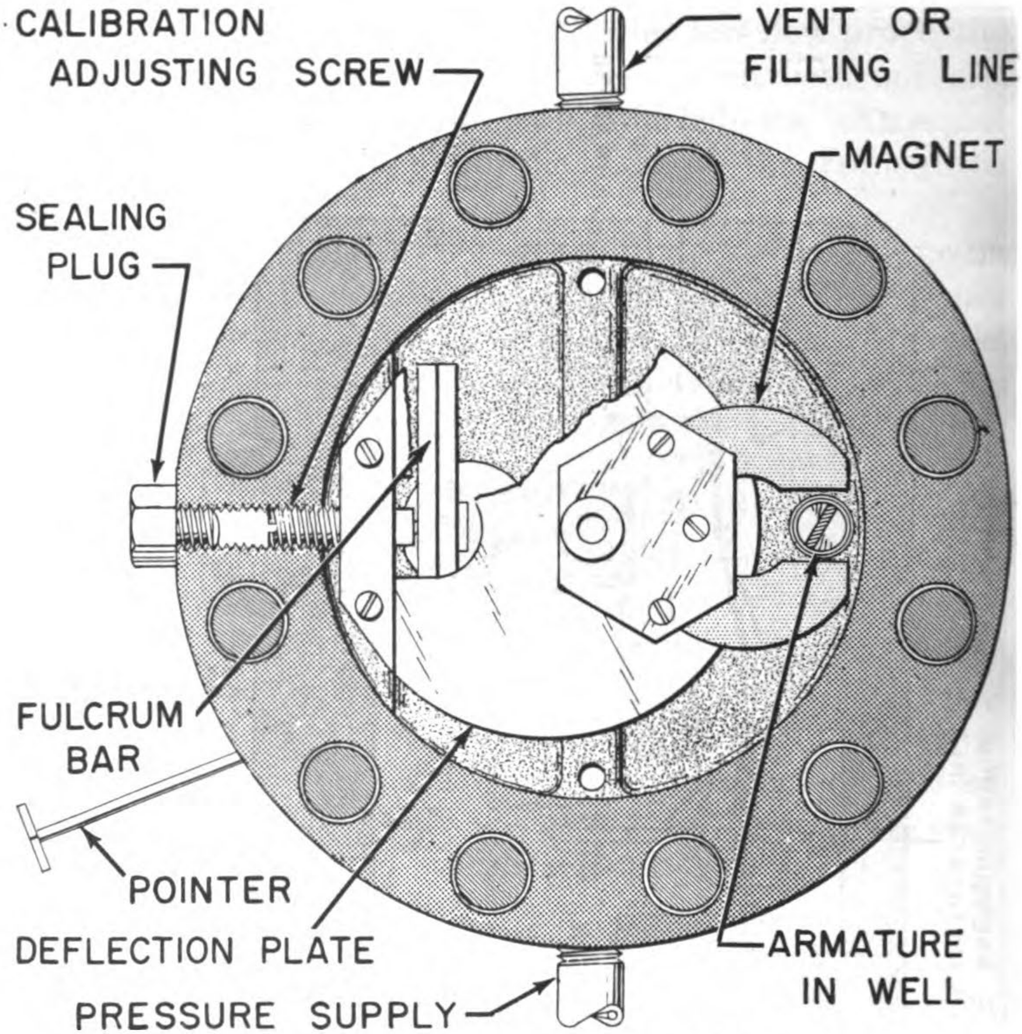


Figure 4–9.—Cross section of indicator unit (side view).

the well. As the magnet moves, the spiral-shaped armature rolls in order to keep in alinement with the magnetic field between the poles. Thus a rotary motion is imparted to the armature mounting shaft; and the rotation of the shaft causes the pointer to move. The pointer hand moves over a brightly illuminated vertical dial which is divided into green and red zones to represent safe and unsafe operating conditions.

It is important to note that the armature well forms a pressure-tight seal between the main part of the indicating unit, which is under boiler pressure, and the armature, which is under atmospheric pressure only. The magnet turns the armature, thereby turning the mounting shaft and causing

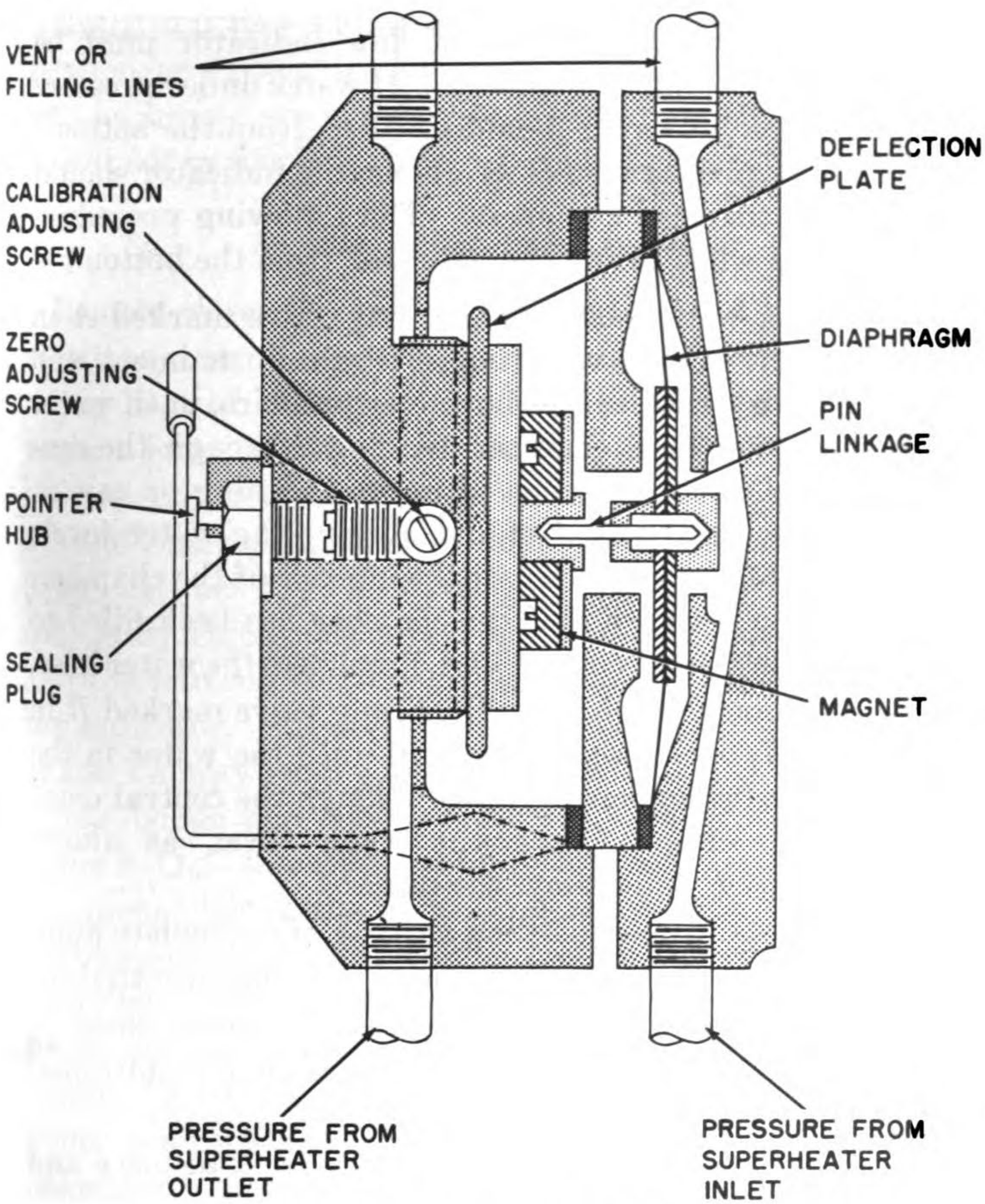


Figure 4–10.—Cross section of indicator unit (front view).

the pointer to move. Thus magnetic force is the only connection between the boiler-pressure side of the instrument and the atmospheric-pressure side. The outstanding advantage of this arrangement is that it allows motion to be transmitted from the boiler-pressure side to the atmospheric-pressure side, through a perfect seal, with a minimum friction loss. As a result, very small changes in pressure differential can be shown on the dial.

The Yarway superheater steam flow indicator must be primed before it is put into service. If water under pressure is available, the indicator should be filled from the bottom; if water under pressure is not available, the indicator should be filled from the head chambers. The following procedure should be used when filling the indicator from the bottom:

1. Connect a water hose to the filling valve marked *A* in figure 4–7. Open valve *A*. Fill the instrument and the piping with clean water under pressure, until water in the upper head chamber overflows through the central overflow connection. Remove the plug or cap on the upper head chamber and observe the water level; use a flashlight to illuminate the interior of the chamber. When you are sure that the chamber has been filled to overflowing, close valve *A* and disconnect the water hose.
2. Connect the water hose to the filling valve marked *B* in figure 4–7, open valve *B*, and fill until the water in the lower head chamber overflows through the central overflow connection. Check the water level, as above. Close valve *B* and remove the hose.
3. Reconnect the hose to filling valve *A* and circulate additional water through the system, to make sure that all air is removed. Close valve *A* and remove the hose.
4. Reconnect the hose to valve *B* and circulate additional water, as above.
5. Put the head chamber plugs or caps back in place and tighten them.

If water under pressure is not available, the indicator should be filled from the head chambers. Remove the plugs or caps from the head chambers and fill the instrument and the connecting piping with water. When the indicator is filled in this way, the vent or filling valves on the indicating unit must be opened periodically until all air has been removed from the system.

When the head chambers are filled to the overflow level and all air has been removed from the system, the indicator should read zero under cold boiler conditions. All super-

heater steam flow indicators are factory set for correct indication, and normally require no further adjustment. The zero adjusting screw and the calibration adjusting screw should not be touched except in cases of absolute necessity.

Remote Water Level Indicator

Remote water level indicators are installed in some naval vessels to show the water level in the steam drum. The indicating part of the instrument may be mounted at any convenient location below the level of the steam drum. The component parts of the remote water level indicator are: (1) the boiler unit, which is mounted on the end of the steam drum, between the two water gage glasses; (2) a graduated indicator, which is usually mounted on an instrument panel; and (3) two copper tubes, which connect the boiler unit and the indicator. Figure 4–11 shows the general arrangement of the Yarway remote water level indicator.

The boiler unit has two chambers, marked *A* and *B* in figure 4–11. A constant water level is maintained in chamber *A;* in chamber *B*, the water level varies with the water level in the steam drum. The boiler unit is connected to the steam drum by two pipes. One of the pipes connects the top of the boiler unit to the steam drum, at a point above the highest water level to be indicated. Because of this connection, boiler pressure is exerted equally upon the water in the two chambers. The other (bottom) pipe connects the line from chamber *B* to the steam drum, at a point below the lowest water level to be indicated. Because of this connection, the water level in chamber *B* is equalized with the water level in the steam drum.

As you can see from figure 4–11, each chamber is connected by piping to the indicator, where the columns of water terminate on opposite sides of a diaphragm. The indicating unit itself is almost identical to the indicating unit of the Yarway superheater steam flow indicator, previously described. The essential parts of the indicating unit are the

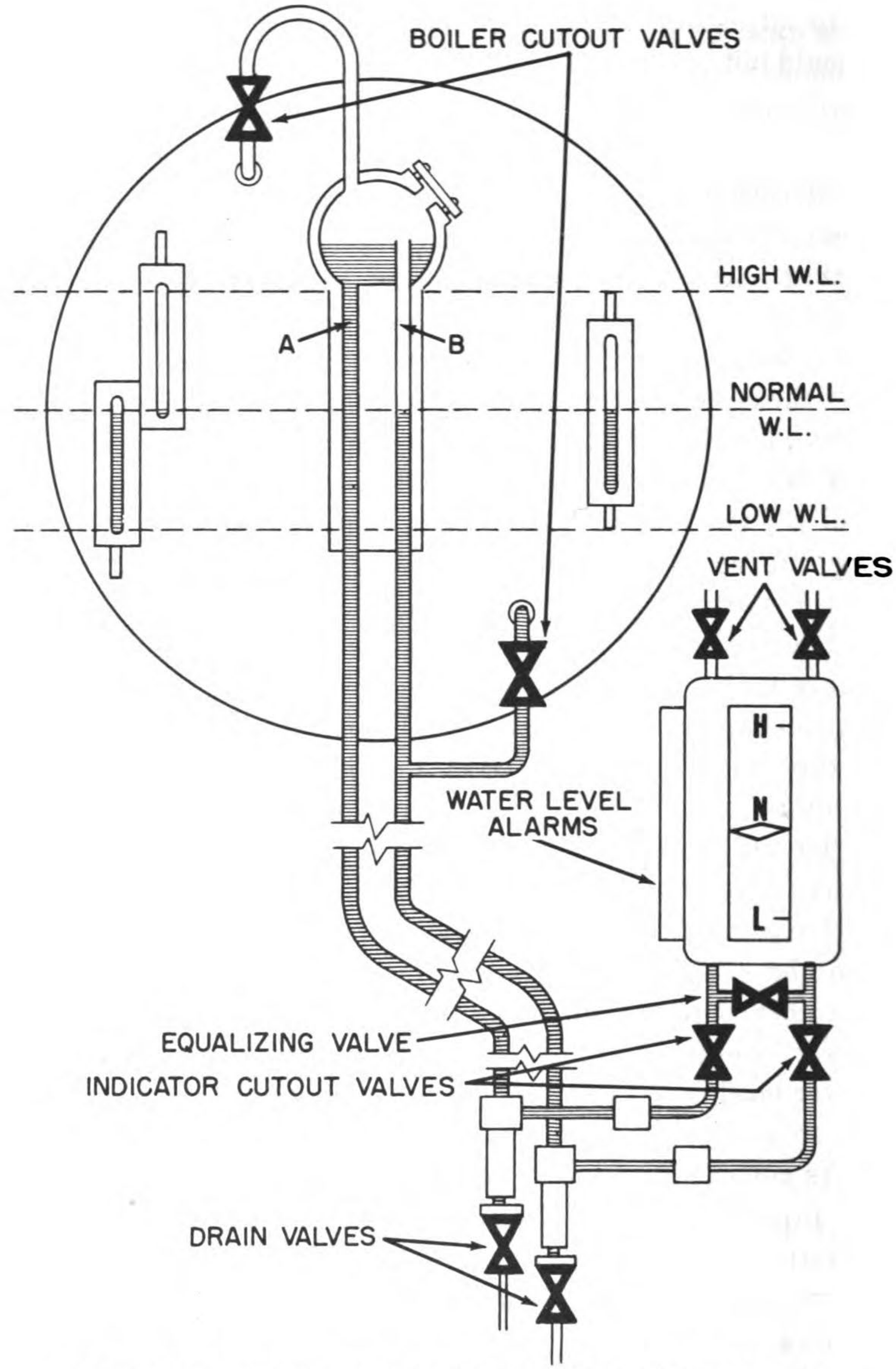


Figure 4–11.—Remote water level indicator (general arrangement).

diaphragm, the deflection plate with attached magnet, and the spiral strip armature which is attached to the pointer. The pointer moves over an illuminated scale which shows low, normal, and high water levels. In addition, the indicating unit contains two magnetically actuated switches which operate a warning horn when the water level in the steam drum is too low or too high.

The remote water level indicator may be placed in operation when the boiler is cold or when it is hot. When the boiler is cold, follow this procedure:

1. Open the boiler cutout valves, the indicator cutout valves, and the equalizing valve.
2. Remove the priming connection cap and fill the system with water.
3. Open the vent valves frequently during filling, in order to purge the system of air. It is essential that all air be removed from the system.
4. Replace the priming connection cap and close the vent valves.

To place the remote water level indicator in service when the boiler is hot, follow this procedure:

1. Close the two indicator cutout valves.
2. Open the boiler cutout valves.
3. Allow the tubing to cool to about room temperature.
4. Open the equalizing valve.
5. Open the two indicator cutout valves.
6. Blow down the drain valves lightly, first one and then the other.
7. Open the vent valves alternately, first one and then the other, until all air has been expelled from the system. DO NOT ALLOW THE HOT BOILER WATER TO REACH THE INDICATOR.
8. Close the equalizing valve tightly.
9. Wait a few minutes before reading the instrument. The reading will not be accurate until the constant level chamber has had time to fill with condensate.

A tachometer is an instrument which shows the rate at which a shaft is rotating. Tachometers are used to indicate the revolutions per minute (rpm) of propeller shafts, turbines, generators, blowers, pumps, and many other kinds of shipboard machinery.

Some types of machinery are equipped with permanently mounted tachometers. However, most fireroom machinery must be checked with a portable tachometer, which is applied manually to the depression or projection at the center of the moving shaft. Each portable tachometer comes supplied with several hard-rubber tips. In order to use the instrument, you must select the tip with the proper shape, fit it over the end of the instrument's drive shaft, and hold it against the center of the moving shaft. Some tachometers are also supplied with a small wheel which can be fitted to the end of the drive shaft and used to measure the linear velocity of a wheel or journal. (When measuring linear velocity, of course, you must hold the tachometer so that the attached wheel is in contact with the OUTER SURFACE of the moving object.)

Portable tachometers should be used only for intermittent readings, not for continuous operation. In using a portable tachometer, be sure that the tachometer shaft is in line with the rotating shaft. Never try to use a tachometer to measure a rotational speed higher than the maximum speed shown on the tachometer dial—if you do, you will ruin the instrument.

The tachometers you are most likely to be using are the centrifugal type, the chronometer type, and the resonance type. The stroboscopic tachometer is also described here, since you may have some occasion to use it.

The basic principles of the CENTRIFUGAL TACHOMETER are described in *Fireman*, NavPers 10520-A. In this instrument, centrifugal force acts upon weights or flyballs which are connected by links to an upper and a lower collar. The upper collar is fixed to the drive shaft, but the lower collar is free to move up and down the shaft. A spring, which fits

over the drive shaft, connects the upper collar and the lower collar. As the drive shaft begins to rotate, the flyballs spin around with it. Centrifugal force tends to pull the flyballs away from the center, thus raising the lower collar and compressing the spring. The lower collar is connected to the pointer, and the upward movement of the collar causes the pointer to move to a higher rpm reading on the dial. The centrifugal tachometer registers rpm of a rotating shaft as long as it is in contact with the shaft; and for this reason it is called a CONSTANT-READING tachometer.

The CHRONOMETER TACHOMETER is not a constant-reading instrument. After you hold it against the rotating shaft, you have to push a starting knob on the side of the case before the instrument will begin to operate. The pointer then moves across the dial and stops at the operating rpm of the rotating shaft. When the instrument is removed from the rotating shaft, the pointer stays in position until the knob on the side is pushed in again. The chronometer tachometer is essentially a stop-watch type of device.

The RESONANCE TACHOMETER consists of a number of steel reeds, each one of which vibrates at a different frequency. The reeds are fastened in a row, in order of frequency; and the row is mounted with the reeds at right angles to the back of the instrument. The unattached ends of the reeds extend through a horizontal slit in the face of the instrument. The scale is stamped along the slit. When the instrument is solidly attached to the foundation or casing of a rotating machine, the reed which is nearest in frequency to the rpm of the rotating machine will begin to vibrate. Resonance tachometers are particularly useful for measuring high rotational speeds such as occur in turbines, generators, and forced draft blowers; but they are not as accurate as other types of tachometers.

The STROBOSCOPIC TACHOMETER is a device which allows rotating, reciprocating, or vibrating machinery to be viewed intermittently, in such a way that the movement appears to be slowed, stopped, or reversed. Because the illumination

is intermittent rather than steady, the eye receives a series of views rather than one continuous view.

When the speed of the flashing light coincides with the speed of the moving machinery, the machinery appears to be motionless. This effect occurs because the moving object is seen each time at the same point in its cycle of movement. If the flashing rate is decreased slightly, the machinery appears to be moving slowly in its true direction; if the flashing rate is increased slightly, the machinery appears to be moving in the reverse direction. To measure the speed of a mechanism, therefore, you find the rate of intermittent illumination at which the machinery appears to be motionless. To observe the operating machinery in slow motion, you adjust the stroboscope until the machinery appears to be moving at the desired speed.

The stroboscopic tachometer furnished for shipboard use is a small, portable instrument. It is calibrated so that you can read speed directly in rpm from the control dial. The flashing speed is determined by a self-contained electronic pulse generator which can be adjusted, by means of the direct-reading dial, to any value between 600 and 14,400 rpm. Because the stroboscopic tachometer is never used in direct contact with moving machinery, it is a particularly useful instrument for measuring the speed or observing the operation of machinery which is run by a relatively small power input, or machinery which is installed in inaccessible places.

APPARATUS FOR ANALYSIS OF COMBUSTION GASES

Several kinds of apparatus are available for use in determining the carbon dioxide content of stack gas. The type most commonly used on board ship is the Orsat flue gas analyzer, which you have already learned about in *Fireman*, NavPers 10520–A. In the Orsat method, the quantity of carbon dioxide is determined by drawing off a sample of known volume of the mixed gases (carbon dioxide, oxygen, and carbon monoxide) and then removing the carbon dioxide by a process of chemical absorption. If necessary, the oxy-

gen content and the carbon monoxide content may also be determined with the Orsat analyzer.

Other types of apparatus which you may have occasion to use for flue gas analysis include a mechanical CO_2 indicator and recorder, and various types of electrical analyzers. The mechanical CO_2 indicator and recorder depends for its operation upon the fact that the specific weight of stack gas increases in proportion to the carbon dioxide content, since carbon dioxide is about 50 percent heavier than the other constituents of stack gas. Electrical methods of analysis allow determination of the carbon dioxide content by measuring electrical or thermal conductivity of a stack gas sample.

QUIZ

1. What term is used to describe a single pressure gage which registers both vacuum and gage pressure?
2. When gage pressure is 60 psi, what is the absolute pressure?
3. What term is used to describe actual atmospheric pressure, rather than standard atmospheric pressure?
4. What reading on a vacuum gage (inches of mercury) corresponds to an absolute pressure of 12 inches of mercury?
5. Convert 19 inches of mercury vacuum to psi absolute.
6. Convert 15 psi (gage pressure) to inches of mercury (absolute pressure).
7. A steam pressure gage which is connected 6 feet below the pressure line shows 235 psi. The gage has not previously been corrected for a head of water. What is the actual pressure in the steam line?
8. What protection must be provided for the Bourdon tube in a pressure gage used for steam service?
9. If a pressure gage cannot be made to read correctly over the entire scale, how should it be adjusted?
10. What type of hydraulic fluid should be used in dead-weight pressure gage testers?
11. What are the three main parts of a distant-reading thermometer?
12. Under what circumstances would shipboard recalibration of superheater outlet thermometers be necessary?
13. Under what circumstances will the superheater temperature alarm fail to give warning of dangerous temperatures in the superheater?
14. What pressure difference is used to measure rate of steam flow through the superheater?
15. Why are superheater steam flow indicators calibrated in inches of water, rather than in psi?
16. In the Yarway superheater steam flow indicator, what purpose is served by having one head chamber located 2 inches above the other head chamber?
17. In the Yarway superheater steam flow indicator, what force is used to transmit the pressure differential to the indicating pointer?
18. In the remote water level indicator, what water levels exist in the two chambers of the boiler unit?
19. Why is the centrifugal tachometer called a CONSTANT-READING tachometer?
20. What type of tachometer can be used to measure the speed of moving machinery, without having any direct contact with the machinery?
21. What method of flue gas analysis depends upon the chemical absorption of each gas from a sample of known volume of mixed gases?

CHAPTER 5

AUXILIARY TURBINES

Steam turbines are used to drive many of the auxiliary machinery units installed in modern naval vessels. Turbine-driven auxiliaries located in the engineering spaces include ship's service generators, main condensate pumps, main feed pumps, feed booster pumps, fuel oil service pumps, main lubricating oil pumps, main circulating pumps, and forced draft blowers.

As a Boilerman, you will need to know a good deal about pumps and forced draft blowers. These two subjects will be discussed in the next two chapters. In this chapter we will take up the auxiliary turbines which drive the pumps and blowers. You will probably find it helpful to study this chapter first, and then to refer back to it as you go on to learn about pumps and forced draft blowers.

It is important to note that the information and instruction contained in this chapter is of a general nature only. Auxiliary turbine installations vary to such an extent that it is necessary to consult the manufacturer's instruction book for detailed instructions for any given unit. Further information on auxiliary turbines may also be obtained from chapter 50, BuShips *Manual.*

DEFINITIONS AND CLASSIFICATIONS

The basic distinction made between turbines has to do with the manner in which the steam causes the turbine rotor to move. When the rotor is moved by a direct push or "im-

pulse" from the steam impinging upon the rotor blades, the turbine is said to be an IMPULSE TURBINE. When the rotor is moved by the force of reaction, the turbine is said to be a REACTION TURBINE.

The angle at which the steam hits the moving blades and the shape of the moving blades are the two main factors which determine whether the rotor is moved by a direct impulse or by reaction to an impulse. Figure 5–1 shows the nozzle and blade arrangement in an impulse turbine. Figure 5–2 shows the fixed blades and the moving blades in a reaction turbine.

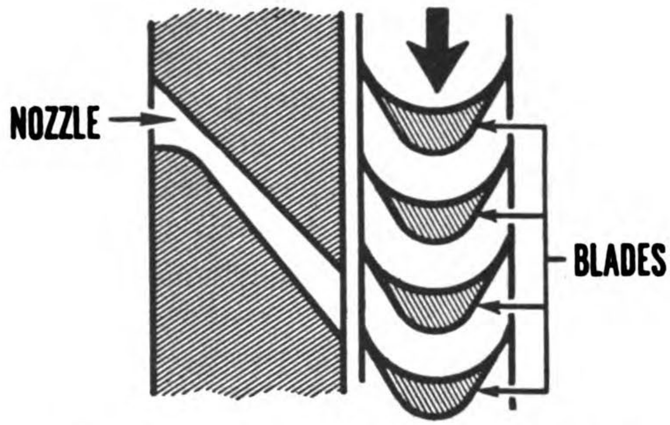


Figure 5–1.—Impulse turbine nozzle and blades.

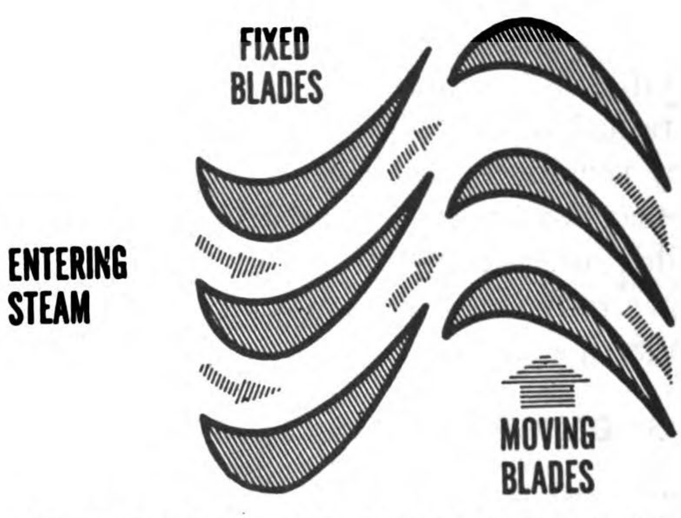


Figure 5–2.—Fixed and moving blades in a reaction turbine.

In the impulse turbine, the steam expands in the nozzle and so loses pressure but gains velocity. In the moving blades, the steam loses velocity but the pressure remains constant. Actually, an impulse turbine utilizes both the impulse of the steam jet and, to a lesser extent, the reactive force which results from the fact that the curving blades cause the steam to change its direction.

In the reaction turbine, the steam enters through a row of fixed blades which direct the flow of steam to the moving blades. As you can see in figure 5–2, the fixed blades and the moving blades are very similar in shape. Steam expansion takes place in both sets of blades.

A reaction turbine is moved primarily by (1) the reactive force produced on the moving blades when the steam increases in velocity, and (2) the reactive force produced on the moving blades when the steam changes direction. However, some of the motion of the rotor is actually caused by the impact of the steam on the blades; and, to a certain extent, therefore, the reaction turbine operates on the impulse principle as well as on the reaction principle.

In the remainder of this chapter, we will be concerned only with impulse turbines, since reaction turbines are seldom if ever used to drive auxiliary units.

Staging and Compounding

In an impulse turbine, a STAGE is defined as one set of nozzles and the succeeding row or rows of moving and fixed blades. Another way of defining a stage is to say that it includes the nozzles and blading in which only one pressure drop takes place. (In an impulse turbine, remember, the only pressure drop takes place in the nozzles. Therefore, the number of sets of nozzles in an impulse turbine indicates the number of stages.)

Figure 5–3 shows a SIMPLE IMPULSE TURBINE. This turbine has one stage, consisting of one set of nozzles and one row of moving blades mounted on the rotor. Simple impulse turbines do not utilize the available energy of the steam as effi-

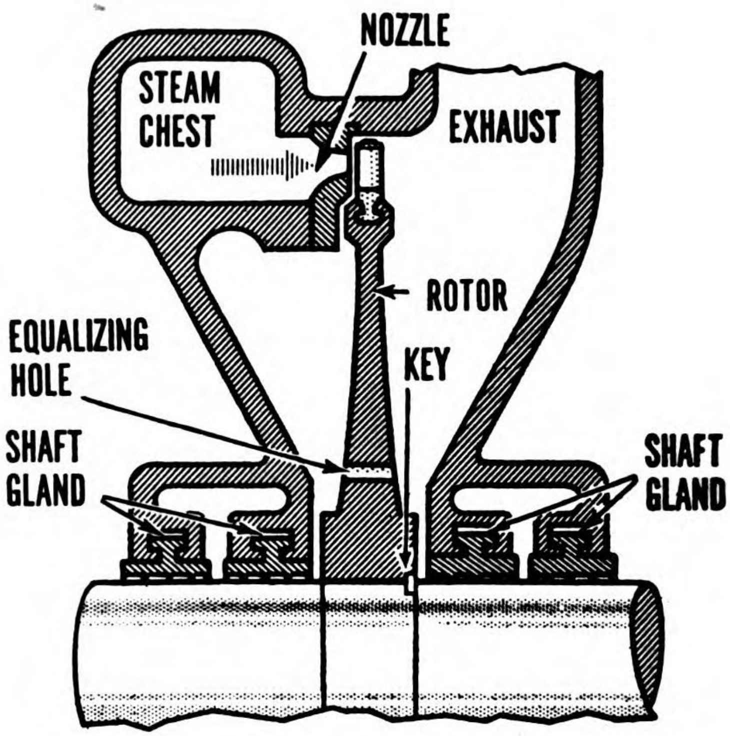


Figure 5–3.—Simple impulse turbine.

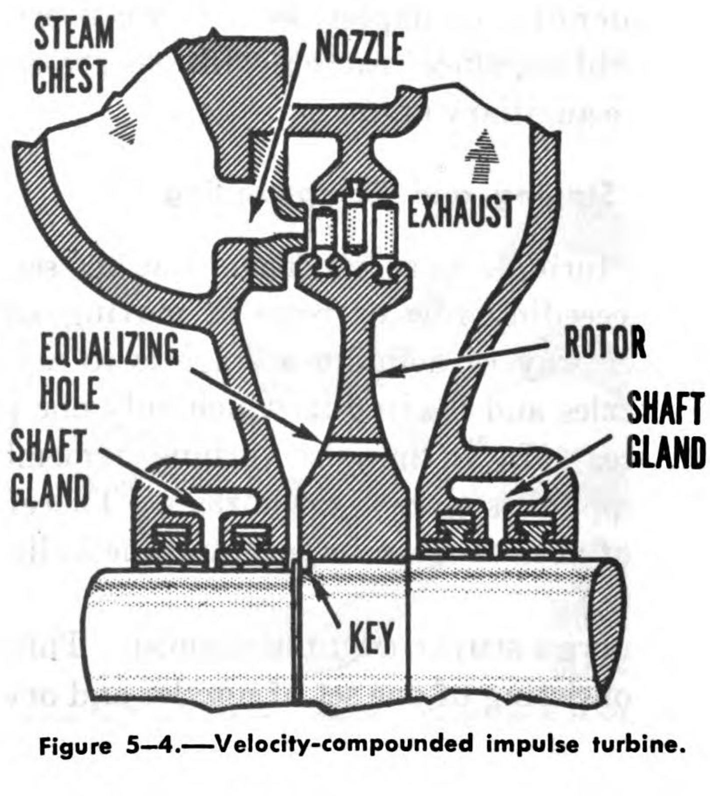


Figure 5–4.—Velocity-compounded impulse turbine.

ciently as multistage turbines. They have the advantage of being simple in design and construction, however, and are often used for small auxiliary units. The simple impulse stage is usually called a RATEAU STAGE.

One way to increase the efficiency of the turbine is to add another row (or even two more rows) of moving blades to the rotor. Figure 5-4 shows a turbine which has two rows of moving blades. This type of turbine is called a VELOCITY-COMPOUNDED IMPULSE TURBINE because the residual velocity of the steam leaving the first row of moving blades is utilized in the second row of moving blades; and, if a third row is added, the velocity of the steam is utilized in the third row. The fixed blades, which are fastened to the casing rather than to the rotor, serve to direct the steam from one row of moving blades to another.

The velocity-compounded impulse turbine shown in figure 5-4 has only one pressure drop and therefore, by definition, only one stage. This type of velocity-compounded impulse stage is usually called a CURTIS STAGE. Many of the auxiliary turbines used for pumps and forced draft blowers consist of one Curtis stage.

(Velocity-compounding can also be achieved when only one row of moving blades is used, provided the steam is directed in such a way that it passes through the blades more than once. We will take up this point in greater detail in the discussion of types of steam flow.)

Another way to increase the efficiency of an impulse turbine is to arrange two or more simple impulse stages in one casing. The casing is internally divided by diaphragms so that the residual steam pressure from one stage is utilized in the following stage. This type of turbine is known as a PRESSURE-COMPOUNDED TURBINE because a pressure drop occurs in each stage, as the steam expands through each set of nozzles. Figure 5-5 shows a pressure-compounded impulse turbine with four stages. A pressure-compounded turbine is often called a RATEAU TURBINE, since it is essentially a series of simple impulse (Rateau) stages arranged in sequence in one

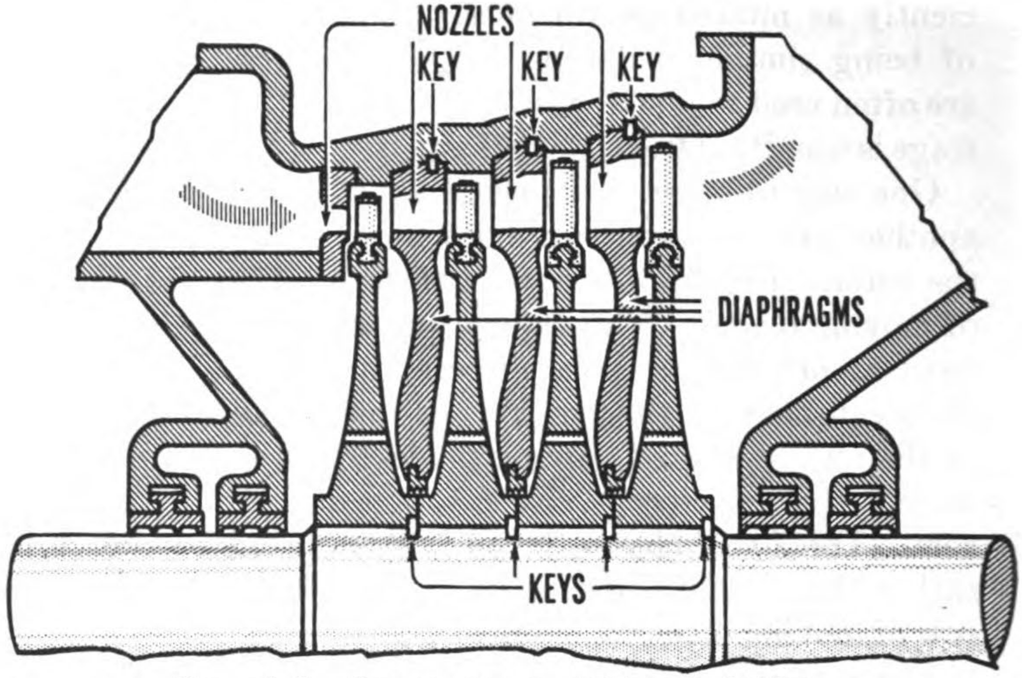


Figure 5–5.—Pressure-compounded impulse turbine.

casing. Pressure-compounded turbines are not commonly used for small auxiliary units.

Various combinations of velocity-compounding and pressure-compounding are used in propulsion and generator turbines. These combinations are not discussed here, since such turbines are seldom used for auxiliary units.

Classification by Steam Flow

Auxiliary turbines may be classified according to the direction of steam flow and according to the repetition of steam flow.

The DIRECTION OF STEAM FLOW may be axial, radial, or helical. In general, the direction of flow is determined by the relative positions of nozzles, diaphragms, rotating blades, and fixed blades.

Most auxiliary turbines are of the AXIAL-FLOW TYPE—that is, the steam flows in a direction which is roughly parallel to the turbine shaft. All of the turbines illustrated thus far in this chapter are axial-flow turbines.

In a RADIAL-FLOW TURBINE, the steam enters in such a way that it flows radially either toward or away from the axis of the rotor. This type of turbine is shown in figure 5–6. Radial-flow turbines are not generally used for propulsion turbines, but are sometimes used for driving smaller auxiliary units, such as pumps.

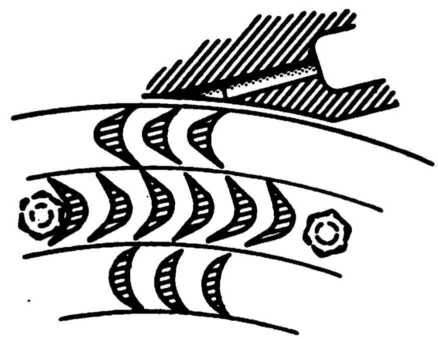


Figure 5–6.—Radial-flow turbine.

In the HELICAL-FLOW TURBINE, shown in figure 5–7, the steam enters at a tangent to the periphery of the rotor and impinges upon the moving blades. These blades, which are usually called BUCKETS, are milled into the rim of the rotor. The buckets are shaped in such a way that the direction of steam flow is reversed in each bucket, and the steam is directed into a REDIRECTING BUCKET or REVERSING CHAMBER mounted on the inner cylindrical surface of the casing. The direction of the steam is again reversed in the reversing chamber; and the continuous reversal of the direction of flow keeps the steam moving helically.

Several nozzles are usually installed in this type of turbine, and for each nozzle there is an accompanying set of redirecting buckets or reversing chambers. Thus the reversal of steam flow is repeated several times for each nozzle and set of reversing chambers.

How would you classify the helical-flow turbine, with respect to staging and compounding? It is a SINGLE-STAGE turbine because it has only one set of nozzles and therefore only one pressure drop. It is a VELOCITY-COMPOUNDED turbine because the steam passes through the moving blades

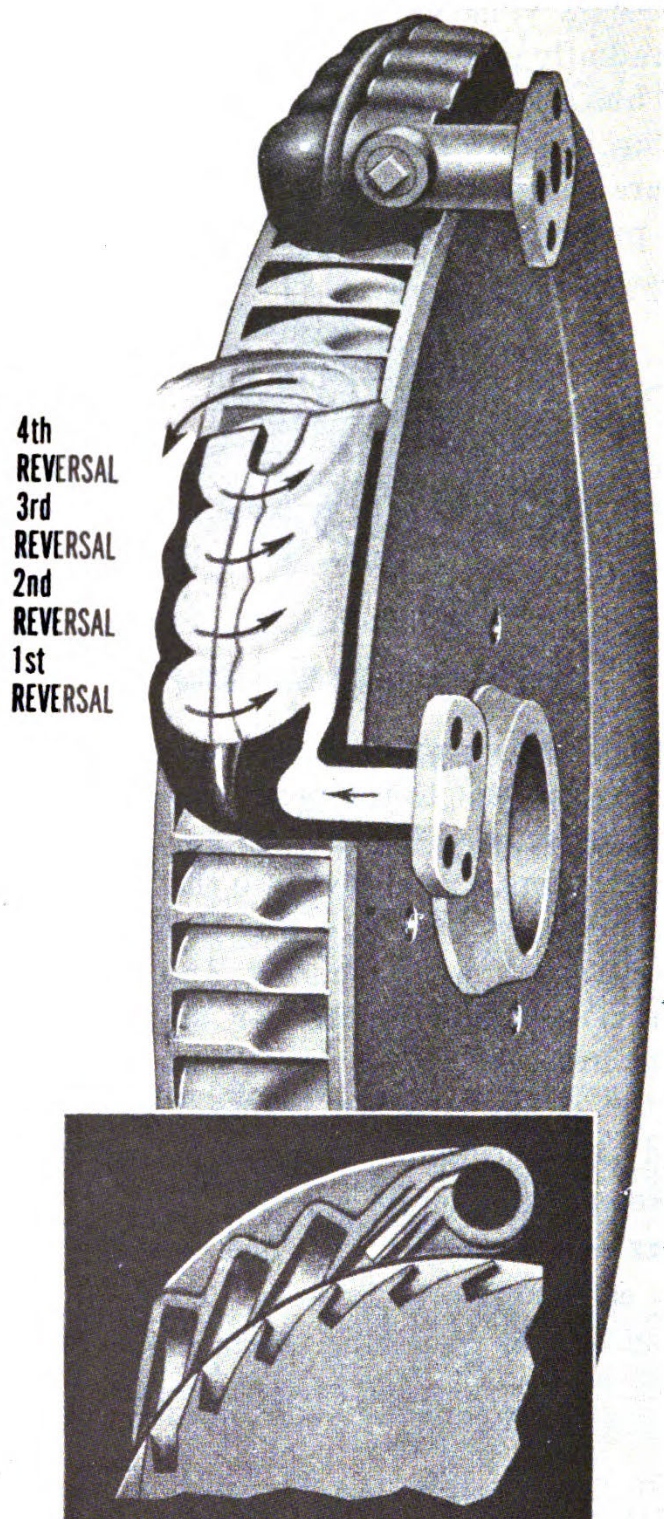


Figure 5–7.—Helical-flow turbine.

(buckets) more than once, and the velocity of the steam is therefore utilized more than once. (The helical-flow turbine shown in figure 5–7 might be said to correspond roughly to a turbine in which velocity-compounding was achieved by the use of four rows of moving blades.)

Helical-flow turbines are used for driving forced draft blowers and pumps.

Turbines are classified as being single entry or re-entry, according to the REPETITION OF STEAM FLOW. If the steam passes through the blades only once, the turbine is called SINGLE ENTRY. All multistage turbines are single entry.

RE-ENTRY turbines are those in which the steam passes more than once through the blades. The helical-flow turbine shown in figure 5–7 is a re-entry turbine. Another type of re-entry turbine is shown in figure 5–8. This turbine is similar in principle to the helical-flow turbine, except that it has one large reversing chamber instead of a number of

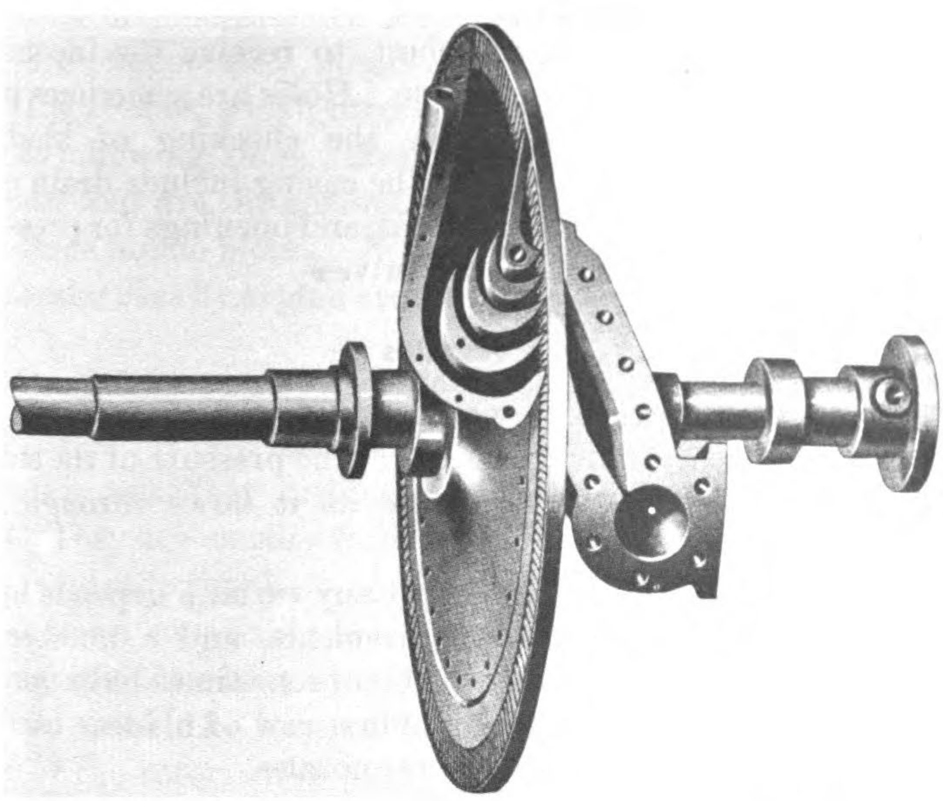


Figure 5–8.—Re-entry turbine with one reversing chamber.

smaller buckets or redirecting chambers. Re-entry turbines are sometimes made with two reversing chambers, rather than one.

TURBINE CONSTRUCTION

A turbine consists primarily of a rotor, which carries the blades; a casing, in which the rotor revolves; and nozzles or stationary blading through which the steam is expanded or directed. In addition, bearings, shaft glands, lubrication equipment, devices for the control of turbine speed, flexible couplings, and—in some cases—reduction gears, are required for the efficient design of the unit as a whole.

Casings

Most auxiliary turbine casings are made of cast carbon steel. Turbine casings are divided horizontally, as a rule; however, the casings for some auxiliary turbines are divided vertically. Flanged joints are accurately machined to make a metal-to-metal fit, and the flanges are bolted together.

Each casing has a steam chest, to receive the incoming steam, and an exhaust connection. Holes are sometimes provided in the casing to allow the checking of blading clearances. Other openings in the casing include drain connections, steam bypass connections, and openings for pressure gages, thermometers, and relief valves.

Nozzles

In an impulse turbine, nozzles guide the steam from the steam chest to the moving blades. The pressure of the steam drops and its velocity increases as it flows through the nozzles.

The arrangement of nozzles in any turbine depends upon load requirements, power requirements, and a number of design factors. Propulsion turbines sometimes have nozzles arranged all the way around the first row of blades. Auxiliary turbines, however, have fewer nozzles.

The number of nozzles used in auxiliary turbines is quite varied. When the amount of steam admitted to the steam

chest is controlled by a throttle valve, the regular nozzles are always open to the steam in the steam chest. An overload nozzle may be opened manually when it is necessary to operate the turbine under conditions of overload or low steam pressure. In other turbine installations, a full head of steam is admitted to the steam chest and a group of nozzle valves (usually four or five) are used in sequence to control the amount of steam admitted from the steam chest to the nozzles.

A nozzle is essentially an opening or a passageway for the steam; so when we speak of nozzle construction, we are actually concerned with the construction of the NOZZLE BLOCK in which the opening occurs. Nozzle blocks are made of corrosion-resistant steel, copper-nickel alloy, or other suitable alloy. They may be cast in solid sections and then machined, or they may be built up by means of vanes and partitions. In cross section, nozzles may be square, rectangular, or round, depending upon the general design of the turbine.

Nozzle diaphragms are installed before each stage of a pressure-compounded impulse turbine. The diaphragms hold the nozzles, which direct the steam against the blading of the following stage. Nozzle diaphragms serve the same purpose and are, in general, similar in construction to the first-stage nozzle blocks. In the nozzle diaphragm, however, the nozzles usually extend around the entire circle.

Rotors

When steam hits the blades on the rotor, the rotor turns. Rotors in auxiliary turbines are generally made of carbon steel. They are usually forged separately, machined, shrunk or pressed onto the shaft, and keyed to the shaft. On impulse turbines, an equalizing hole is drilled through the rotor to prevent the development of a pressure difference between the two sides. As long as the pressure is the same on both sides of the rotor, an impulse turbine has very little thrust. After all parts of the rotor have been made, finished, and assembled, the rotor is dynamically balanced.

Blades

Blades for impulse turbines are made from corrosion-resistant steel or Monel metal. As a rule, the blades are made by machining solid bar stock; however, some blades are made by forging and are finished by machining. All blades are machined to a smooth finish, in order to reduce friction to a minimum. Although there are many variations in the design of blades, most impulse blades are symmetrical and are shaped in the form of a semicircular arc.

Blade roots are dovetailed or serrated, and are shaped to match the shape of the groove around the periphery of the rotor. The blades are inserted in this groove and are held in place by calking pieces, tapered wedges, or similar locking devices.

The outer circumference of each row of impulse blading is fitted with a band or cover, which is fastened to a projection at the tip of each blade. This band is called SHROUDING. The shrouding is installed in order to stiffen the blades and thus reduce the amount of vibration. In addition, shrouding serves to keep steam from flowing out over the ends of the blades. When the blades are relatively short, shrouding is sometimes made integral with the blades, instead of being fastened over them. In this case, the integral shrouding of each blade fits very close to the back of the next blade.

Bearings

Turbine rotors are supported and kept in position by bearings. The bearings which serve to maintain the correct radial clearance between the rotor and the casing are called RADIAL BEARINGS. The bearings which serve to limit the axial (longitudinal) movement of the rotor are called AXIAL or THRUST BEARINGS.

One radial bearing is generally used on each side of the rotor. However, some auxiliary turbines are so designed that the two radial bearings are both on the same side of the rotor.

Either ball bearings or sleeve bearings may be used as radial bearings on auxiliary turbines. Figure 5–9 shows a

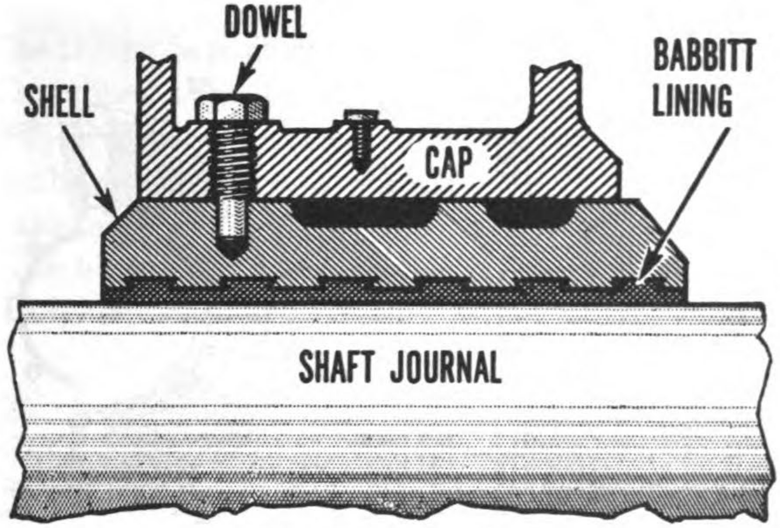


Figure 5–9.—Cylindrical sleeve bearing.

typical sleeve bearing of the cylindrical type. The shell of the bearing is lined with babbitt, a relatively soft metal composed of tin, copper, antimony, and a small amount of lead. Babbitt metal is used for bearing linings because of its ability to dissipate the heat of friction and transfer it to the lubricating oil. In the bearing shown in figure 5–9, the bearing shell is held stationary within the bearing housing by a dowel.

In theory, impulse turbines do not develop end thrust, and therefore should not require thrust bearings. In reality, however, a small amount of end thrust is developed; and this must be absorbed in some way.

In some auxiliary turbines, thrust bearings of the ball type or roller type are used. In others, the radial bearing is designed to present a small axial bearing surface, as well as the radial bearing surface; this type of bearing is actually, therefore, a combination radial and thrust bearing.

In larger auxiliary units, such as forced draft blowers, the Kingsbury thrust bearing is commonly used to absorb thrust. This type of bearing is shown in figures 5–10 and 5–11.

The Kingsbury thrust bearing consists of a THRUST COLLAR, which is keyed to the turbine shaft; tilting segments, called SHOES; the UPPER LEVELING PLATES, upon which the shoes

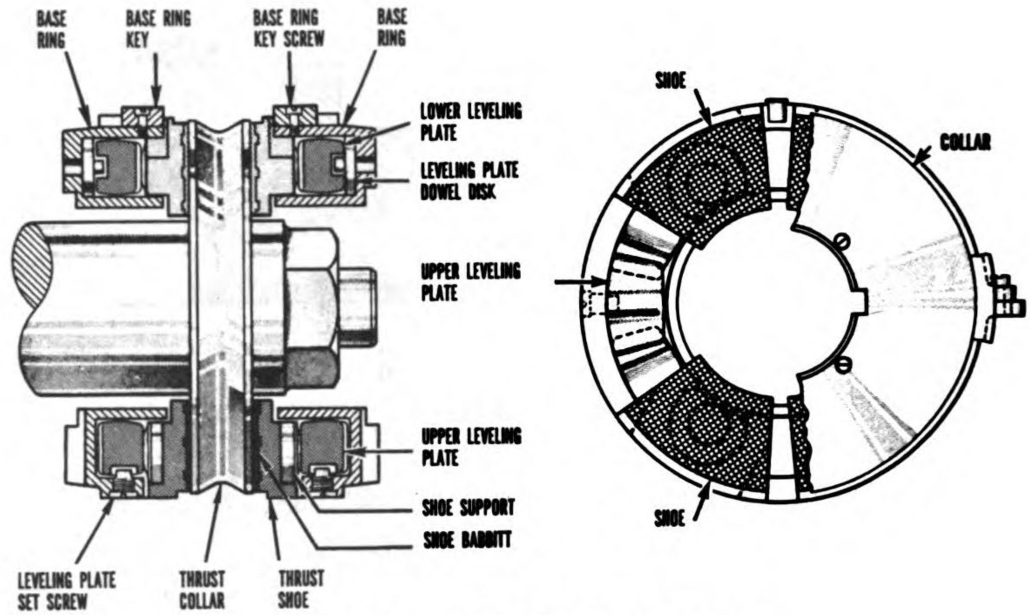


Figure 5–10.—Kingsbury thrust bearing.

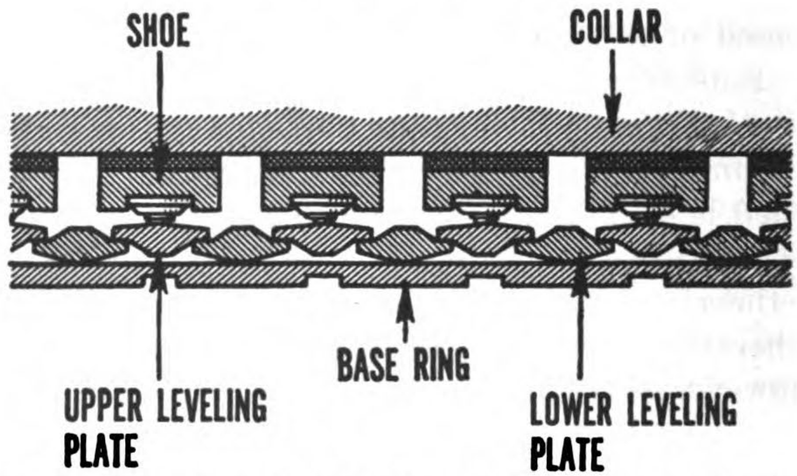


Figure 5–11.—Arrangement of parts in Kingsbury thrust bearing.

rest; the LOWER LEVELING PLATES, upon which the upper leveling plates rest; and the BASE RING, upon which the lower leveling plates rest.

The shoes pivot on the upper leveling plates in such a way that they may be tilted very slightly (about 0.001 to 0.002 inch), and this pivoting arrangement allows the formation of a continuous wedge-shaped oil film between the shoes and the thrust collar. The collar turns with the turbine shaft. The leveling plates serve to equalize the thrust load among all the shoes. The base ring supports the leveling plates.

Turbine thrust is usually in one direction only. However, some Kingsbury-type thrust bearings have shoes on both sides of the collar, to take care of thrust in both directions. In other thrust bearings, a plain babbitted ring is used for the non-thrust side.

A thrust bearing may be installed in a separate housing, or it may be enclosed within the radial bearing housing.

Shaft Glands

Shaft glands are used to keep steam from leaking out of the turbine casing, at the points where the shaft extends through the casing. The shaft glands on auxiliary turbines have a gland housing which may be a part of the turbine casing or may be a separate housing bolted to the casing. Two types of packing are used—labyrinth packing and carbon packing. They may be used either separately or in combination.

LABYRINTH PACKING consists of rows of metallic strips or fins. These strips are fastened to the gland liner in such a way as to make a very small clearance between the strips and the shaft. As the steam from the turbine casing leaks through the small spaces between the packing strips and the shaft, its pressure is gradually reduced.

CARBON PACKING RINGS also serve to restrict steam leakage along the shaft in the manner just described. Carbon rings are mounted around the shaft and are held in place by springs. As a rule, three or four carbon rings are used in each gland; each ring is fitted into a separate compartment of the gland housing. Each ring consists of two, three, or four segments which are butt-joined to each other. Lugs or stop pins are used to keep the carbon rings from rotating with the shaft. The outer carbon ring compartment is connected to a drain line.

REDUCTION GEARS

Turbines must operate at relatively high speeds to utilize the steam most efficiently. The driven auxiliary units, on the other hand, are frequently most efficient when operating

at lower speeds. Reduction gears are used to transmit rotary motion from the driving turbine shaft to the shaft of the driven auxiliary, while allowing each unit to operate at its most efficient speed.

In many installations, reduction gears also serve to change the direction of motion. Thus, a pump shaft which is perpendicular to the driving turbine shaft will be connected by reduction gears which serve both to reduce the speed and to change the plane of rotation.

With the exception of forced draft blowers, fans, and high-speed centrifugal pumps, most turbine-driven auxiliary units on board ship employ reduction gears. As a rule, the high-speed units are direct-drive, while the low- or moderate-speed units are geared.

FLEXIBLE COUPLINGS

Many turbine-driven auxiliary units are joined to the turbine by means of a flexible coupling which takes care of very slight misalinement between the driving and the driven shafts. Forced draft blowers are usually made with a single shaft for both turbine and fan; but most other fireroom auxiliaries are made with separate shafts for the driving and driven units. These shafts are joined together by flexible couplings.

Many different designs of flexible couplings are used for auxiliary units, but the types you are most likely to find on naval vessels depend upon gears, grids, pins, or disks to give the required flexibility to the coupling.

Figure 5–12 shows a DOUBLE GEAR FLEXIBLE COUPLING. A hub is fitted to the end of each shaft. External gear teeth on each hub mesh with internal teeth cut in each end of a "floating sleeve." The floating sleeve is made in two parts, which are bolted together. The sleeve fits over the hubs, forming a kind of housing.

Double gear flexible couplings are used for many of the larger auxiliary units. For example, this type of coupling is often used on the main feed pump. Smaller pumps often have a SINGLE GEAR FLEXIBLE COUPLING. This is similar to

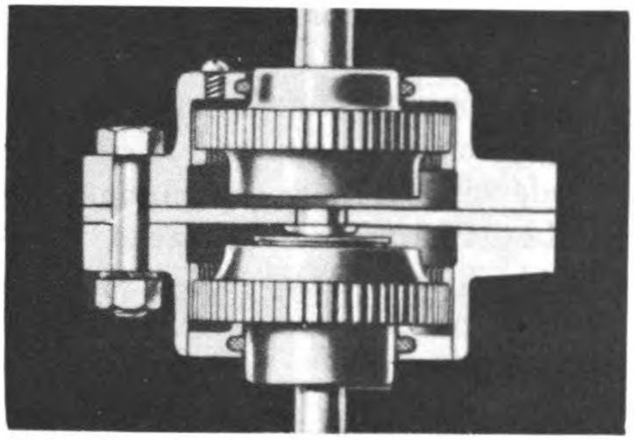


Figure 5–12.—Double gear flexible coupling.

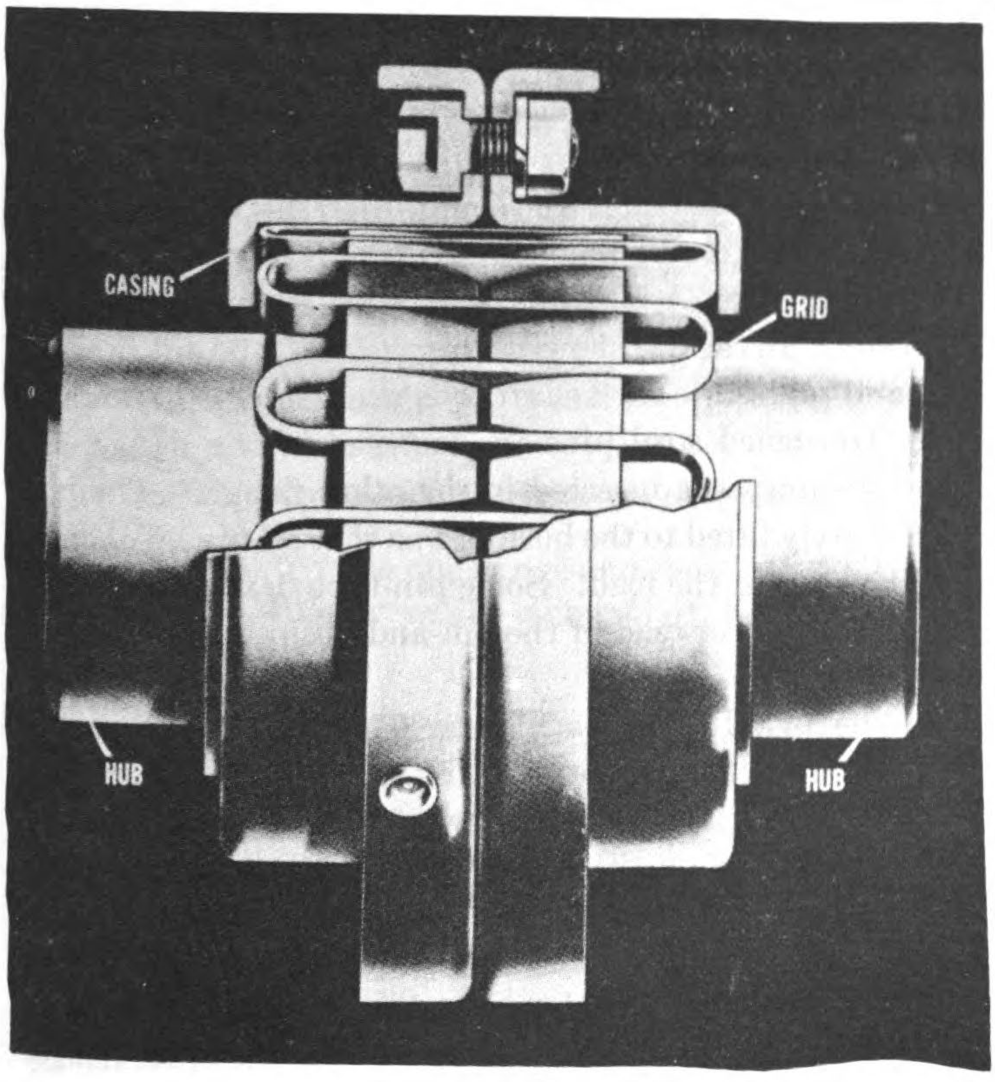


Figure 5–13.—Grid-type flexible coupling.

the double gear coupling, except that it has teeth at only one end of the coupling.

In the double gear coupling shown in figure 5–12, the outer sleeve is the floating member. However, gear-type couplings are sometimes made with an inner floating member. In this case, of course, the outer parts are fastened to each shaft. The outer parts, which are usually called SHAFT RINGS, have internal teeth which mesh with the external teeth on the inner floating member.

The GRID-TYPE FLEXIBLE COUPLING shown in figure 5–13 is quite commonly used to connect small turbines to their driven units. This coupling can absorb minor axial and radial deflections and vibrations without stress on the bearings of the connected units. Each shaft has a flange at the joining end. The flanges are made integral with the shaft or are keyed or welded to it. The flanges are grooved axially around the edge, and a prebent, spring steel grid is fitted into the grooves. The grid thus provides the connection between the two flanges. A split casing holds the grid in place.

There are several different kinds of PIN-TYPE FLEXIBLE COUPLINGS. In the one shown in figure 5–14, a flange is either keyed and pressed to each shaft or is made integral with each shaft. Hardened steel pins are fastened in one flange, and rubber bushings are inserted in the other flange. The pins are accurately fitted to the bushings so that all pins will carry equal portions of the load. Some pin-type flexible couplings use a hinged pin instead of the pin-and-bushing combination shown in figure 5–14.

In some installations, a DISK-TYPE FLEXIBLE COUPLING is used to connect the turbine shaft to the shaft of the auxiliary unit. This coupling consists of two flanges, one on the driving shaft and one on the driven shaft, and an intermediate disk which fits between the two flanges. The disk may be made of leather, rubber fabric, or laminated steel, depending upon the service for which the coupling is used. Bolts from each flange hold the disk, but do not engage the other flange. The bolts from the two flanges alternate, so that the disk is

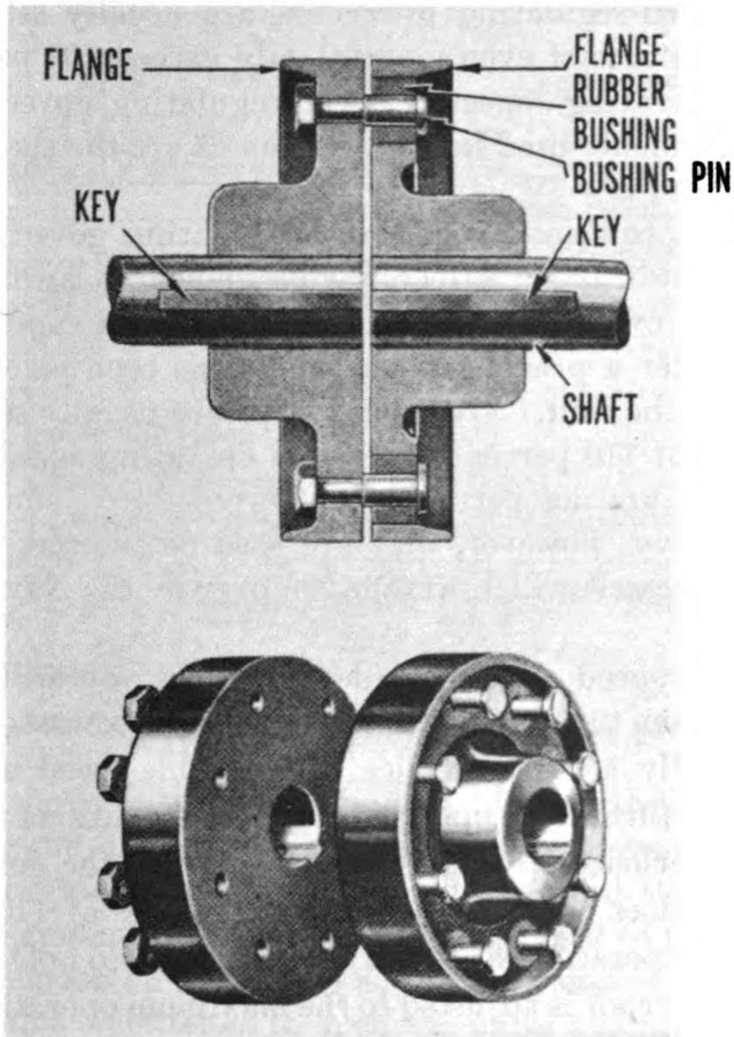


Figure 5–14.—Pin-type flexible coupling.

held first by bolts from one flange and then by bolts from the other, thus giving a small amount of flexibility to the coupling.

OVERSPEED PROTECTION DEVICES

The three kinds of overspeed protection devices which you are most likely to find on fireroom machinery are the speed-regulating governor, the overspeed trip, and the speed-limiting governor.

The SPEED-REGULATING GOVERNOR, sometimes called the CONSTANT-SPEED GOVERNOR, is used on constant-speed machines to maintain a constant speed regardless of the load on the tur-

bine. Speed-regulating governors are usually set so that the turbine cannot even momentarily exceed 105 percent of normal operating speed. Speed-regulating governors are not so commonly used in the fireroom as are the speed-limiting governors.

Turbines equipped with speed-regulating governors may have, in addition, a safety device known as an OVERSPEED TRIP. The overspeed trip shuts off the steam supply to the turbine after a predetermined speed has been reached, and thus stops the unit. Overspeed trips are usually set to trip out at about 110 percent of normal operating speed. Overspeed trips are not permitted on forced draft blowers built for the Navy; however, they are used on blowers in a few auxiliary vessels which were taken over by the Navy during wartime.

The overspeed protection device which you will find on most fireroom turbines is the SPEED-LIMITING GOVERNOR. This is essentially a safety device for variable-speed units. It allows the turbine to operate under all conditions from no-load to overload, up to the speed for which the governor is set, but it does not allow operation in excess of 110 percent of normal operating speed. It is important to note that this type of governor is adjusted to the maximum operating speed of the turbine, and therefore has no control over the admission of steam until the upper limit of safe operating speed is reached.

In the naval service, speed-limiting governors are provided on turbines used for driving almost all types of pumps and forced draft blowers. Most speed-limiting governors are of the centrifugal-weight type, but some speed-limiting governors of the oil-pressure type are also used.

Figure 5–15 shows a CENTRIFUGAL-WEIGHT TYPE SPEED-LIMITING GOVERNOR for a main feed pump. Centrifugal weights are mounted on a hub which rotates with the turbine shaft. As the speed of the turbine increases, centrifugal force causes the free ends of the weights to move outward, compressing the governor spring. This action causes the

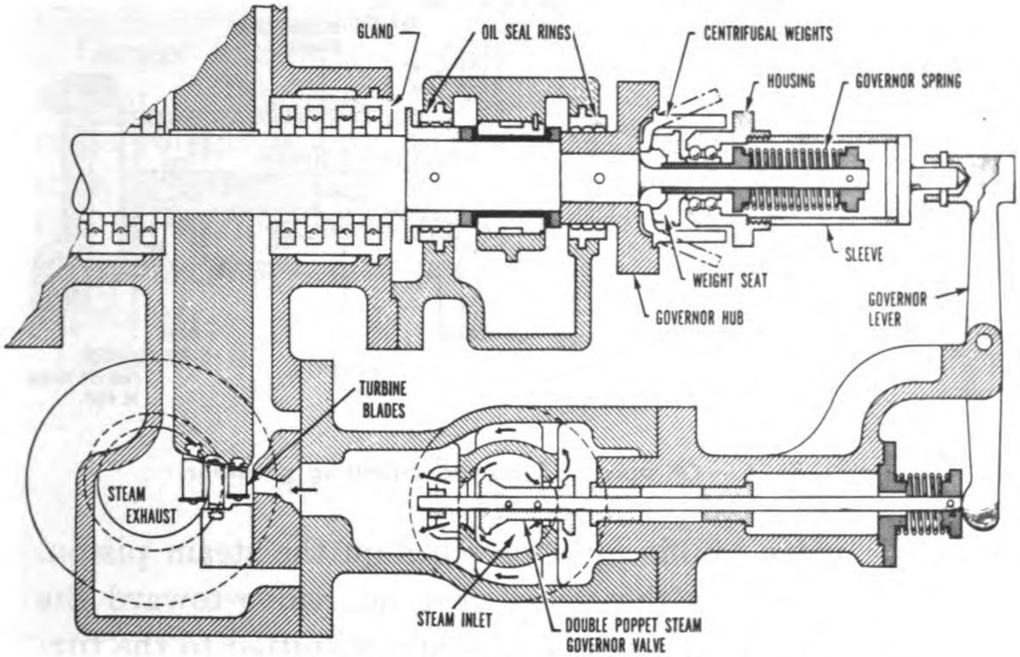


Figure 5–15.—Centrifugal-weight type speed-limiting governor.

sleeve to move out against one end of the governor lever. The other end of the lever is thereby moved inward, closing the double poppet steam governor valve and thus cutting down the amount of steam which is admitted to the turbine rotor. Tension on the spring at the outer end of the double poppet valve stem tends to open the valve again, as soon as the turbine shaft has slowed down and allowed the centrifugal weights to move inward.

An OIL-PRESSURE TYPE SPEED-LIMITING GOVERNOR is shown in figure 5–16. In this type of governor, a centrifugal oil pump, geared to the turbine shaft, delivers oil at a pressure proportional to the speed of the turbine. The pressure acts upon a hydraulic piston in the governor mechanism.

Tension on the speed-adjusting spring opposes the pressure on the hydraulic piston. If the turbine speed exceeds the speed for which the spring is set, the oil pressure becomes greater than the spring tension. This excess of oil pressure overcomes the spring tension and causes the hydraulic piston to move inward; and this action causes the pilot valve to close the return port in the steam governor valve.

When the return port is closed, steam entering through

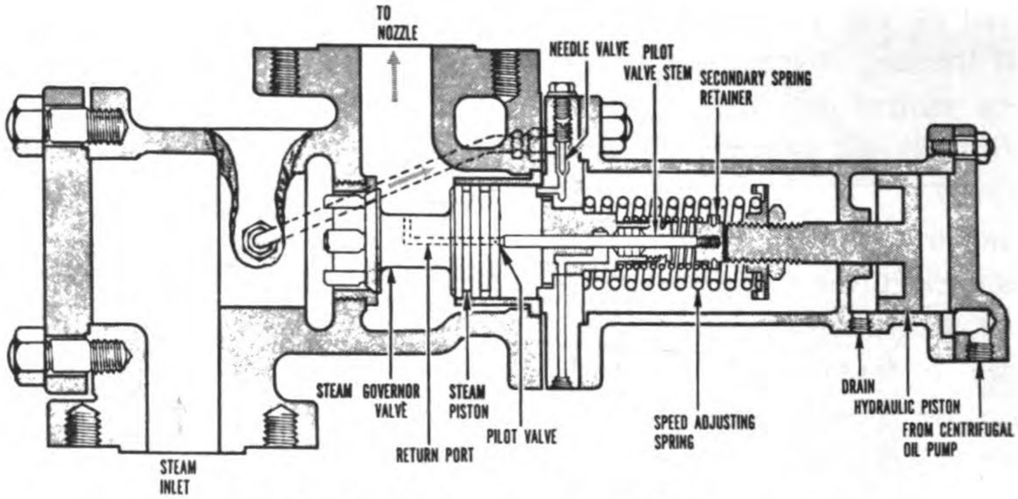


Figure 5-16.—Oil-pressure type speed-limiting governor.

the needle valve builds up a pressure on the steam piston. This pressure moves the steam governor valve toward the closed position. The amount of steam admitted to the turbine is reduced, and the turbine is slowed until a balance is obtained between the oil pressure and the spring tension.

Some speed-limiting governors combine centrifugal weights and oil pressure to limit the speed of the turbine. When the turbine is operating at or below normal speed, the tension on the governor spring prevents the centrifugal weights from moving outward. If the turbine begins to operate at excessive speed, the centrifugal weights begin to move outward, thereby lifting the governor spindle and bringing into action the oil-pressure governing system.

LUBRICATING SYSTEMS

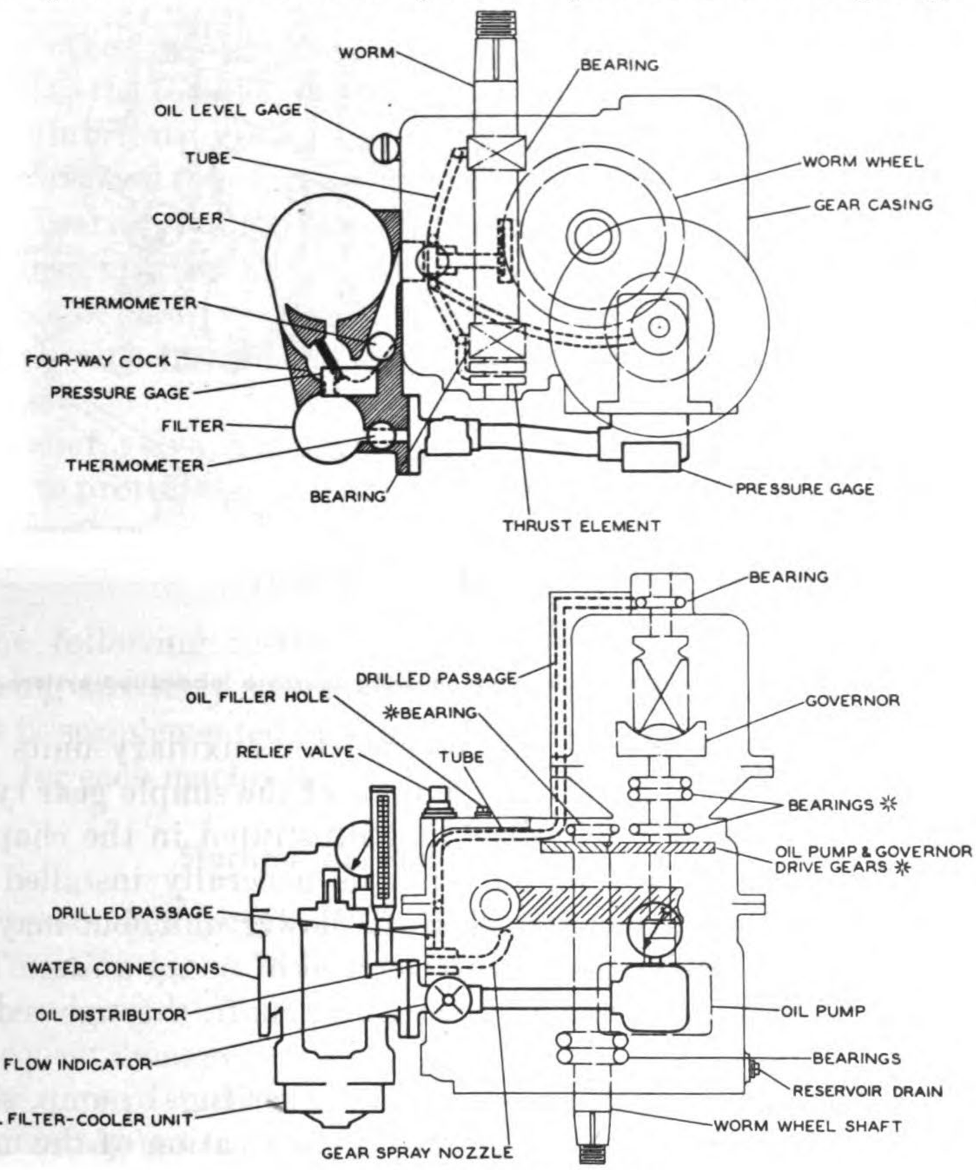
Lubrication is essential to the proper operation of any rotating machinery. In particular, the bearings which support turbine shafts must be well lubricated at all times to permit the free rotation of the turbine rotor.

The bearings on very small auxiliary turbines are often of the self-oiling type. These bearings have one or two rings which hang on the turbine shaft and revolve with it (although at a slower rate). On each revolution, the rings

dip into the oil reservoir and carry oil around to the upper part of the bearing shell.

Larger auxiliary turbines have a pressure lubrication system to lubricate the radial bearings, thrust bearings, reduction gears, and—in some instances—the governor bearings. Pressure lubrication systems do NOT provide lubrication for flexible couplings, governor linkages, and some governor bearings; these parts of the unit must be lubricated separately.

A pressure lubrication system requires a lube oil pump.



✱ LUBRICATED BY OIL DRAINED FROM GOVERNOR

Figure 5–17.—Pressure lubrication system for turbine-driven unit.

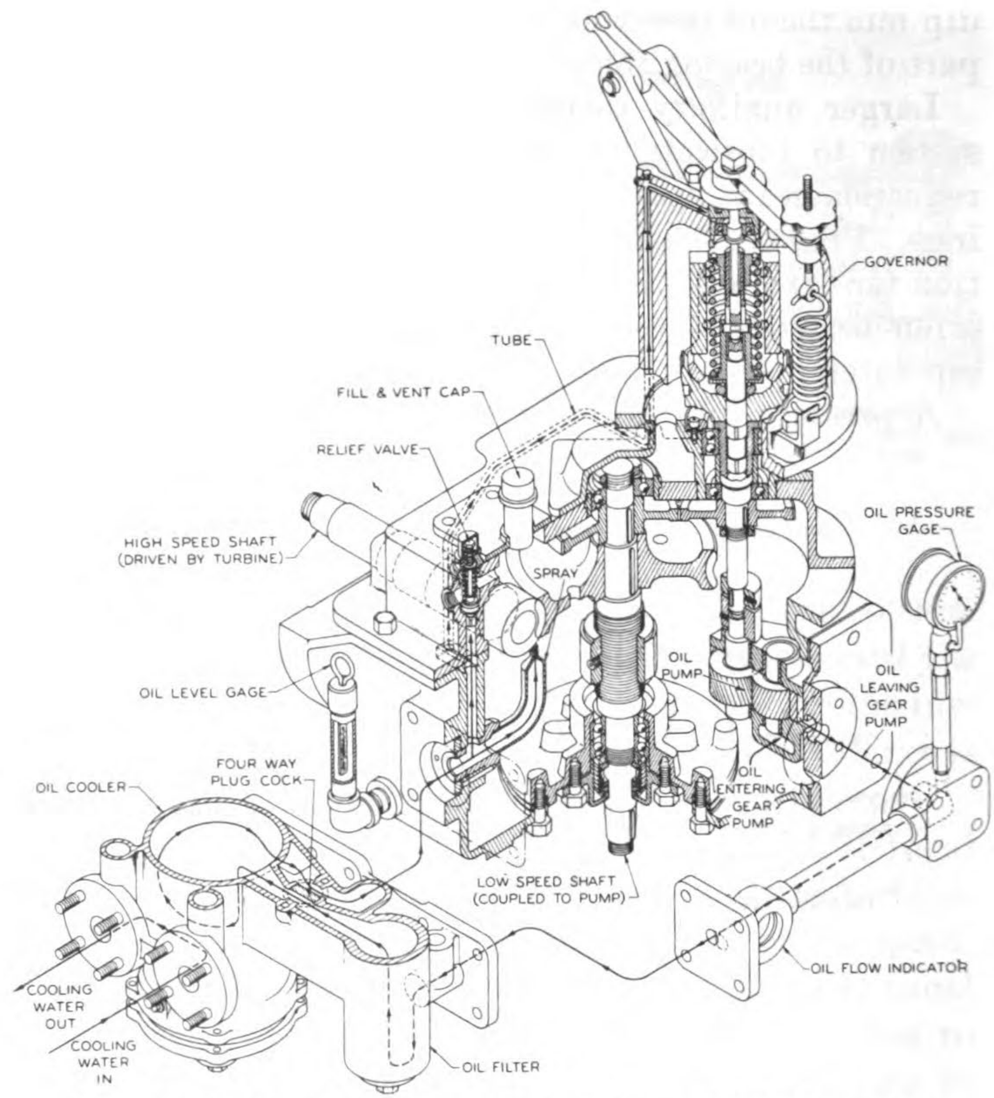


Figure 5–18.—Isometric diagram showing pressure lubrication system.

As a rule, the lube oil pumps used for auxiliary units are positive displacement rotary pumps of the simple gear type. (These pumps are described and illustrated in the chapter on pumps.) The lube oil pump is generally installed on the turbine end of a forced draft blower unit, but may be on either the driving or the driven end of pump units. The lube oil pump is driven by the turbine shaft, through reduction gears.

Some forced draft blowers use a centrifugal pump, supplemented by a viscosity pump, for lubrication of the unit. This type of lubrication system is explained in the chapter on forced draft blowers.

The pressure lubricating system shown in figures 5–17 and 5–18 is designed for fuel oil service pumps, fuel oil booster pumps, and lubricating oil service pumps; however, it is similar in principle to the lubricating systems used on many other units.

In this system, the bottom section of the gear casing forms the oil reservoir. The reservoir is filled through an oil filler hole in the top of the casing, and emptied through a drain outlet at the base of the casing. The shaft which carries the gear-type oil pump on one end and the governor on the other is geared to the pump shaft, which is, in turn, geared to the turbine shaft.

The lubricating oil passes through an oil flow sight, an edge-filtration type filter, and an oil cooler. Oil is then piped to the bearings on the turbine shaft, to the governor, and to the worm gear on the pump shaft. The bearings and gear on the oil pump and governor shaft are lubricated by oil which drains from the governor and passes back into the oil reservoir.

A relief valve is built into the gear casing. This valve serves to protect the system against the development of excessive pressures.

TURBINE OPERATION

The following instructions for starting, operating, and securing auxiliary steam turbines are general in nature, and must be supplemented by study of the manufacturer's instructions for each machine.

Starting an Auxiliary Turbine

A reasonable length of time should always be allowed for starting a turbine. Rapid starting of a turbine would cause sudden changes in internal pressures and temperatures, with consequent damage to the turbine.

The steps in starting an auxiliary turbine are:

1. Check the turbine to be sure that all working parts are clean and well oiled. Test the casing relief valve and the speed-limiting governor by hand, if this is practicable.

2. Check the oil level in the reservoir. The oil should be at or near the maximum mark on the gage or dip-stick. Lubricate the slides and linkage on the speed-limiting governor.
3. Turn the turbine by hand, using a strap wrench or other suitable means. The rotor should revolve easily, without noise or grinding.
4. Open the exhaust valve, UNLESS the exhaust valve is of the spring-loaded type. If it is spring-loaded, do NOT open it at this time.
5. If a constant-pressure pump governor is provided, be sure that the pull-open device has been set in the OPEN position.
6. Open the turbine casing drains and the drains in the branch line from the auxiliary steam line to the turbine throttle. If the branch line is not fitted with a drain, open the turbine throttle and allow water from the branch line to drain into the turbine casing and out through the casing drains. Then crack the steam root valve until steam shows in the turbine drains.
7. Close the throttle valve and open the steam root valve.
8. Check the driven auxiliary, to be sure that it is lined up and in operating condition.
9. Check the flexible coupling to be sure that it is well lubricated.
10. Crack the throttle valve and spin the rotor.
11. Check the oil pressure gage and the oil flow sights, to be sure that the bearings are getting oil. If oil rings are fitted, be sure that they are revolving.
12. Listen for any unusual noise or vibration. If there is any sound of rubbing or grinding, or any vibration, shut down the turbine immediately.
13. Watch the exhaust pressure gage. If the exhaust pressure is excessive, shut down the turbine immediately.
14. If operating conditions appear to be normal, run the turbine slowly for several minutes.
15. If a constant-pressure pump governor is installed, set the pull-open device for automatic operation.

16. Gradually bring the turbine up to approximately operating speed.
17. Close the turbine drains.
18. Open the spring-loaded exhaust valve (if this type of valve is fitted) after the turbine has been brought up to approximately operating speed.
19. If an overspeed trip is fitted, operate it by hand. If the tripping mechanism functions properly, reset the latch.
20. Bring the turbine up to operating speed by adjusting the throttle or the governor.
21. When the temperature of the oil leaving the bearings is about 100° F, cut in the cooling water to the oil cooler.
22. Give the unit a thorough trial under load conditions, before you leave it. In particular, be sure that the unit is being lubricated and that the governor is working properly.

Operating an Auxiliary Turbine

The following instructions should be followed while an auxiliary turbine is in operation:

1. Observe the oil level in the reservoir to be sure that it has not dropped below the normal level. This is particularly important when the turbine is being run for the first time after the oil reservoir has been filled.
2. Apply oil ONCE A DAY to governor oil feed cups and connections between levers of the governing mechanism.
3. Keep a close watch on the oil temperature. Under normal operating conditions, the temperature of the oil leaving the bearings should be about 150° F; it must never be permitted to exceed 180° F. The temperature rise of the oil through any bearing should not exceed 50° F. Oil temperature should be controlled by regulating the flow of cooling water to the oil cooler.
4. Watch for oil, steam, or water seepage. If any occurs, correct the condition which causes it.

5. The edge-filtration type of filter should be cleaned at least once each watch; this is done by giving the handle one or two complete turns.
6. Operate the turbine with the minimum number of nozzles that will carry the load. (Most turbines have only one hand-operated nozzle valve; but some older auxiliary turbines have several.)
7. Keep the exterior of the unit free from dust, dirt, oil, and water.

Securing an Auxiliary Turbine

The steps to be followed in securing an auxiliary turbine are:

1. If a constant-pressure pump governor is in operation, turn the hand wheel to reduce tension on the governor spring. This will slow the pump.
2. Close all hand nozzle valves.
3. If an overspeed trip is fitted, trip it to slow down the turbine.
4. Close the throttle valve.
5. If a constant-pressure pump governor is in operation, set the pull-open device in the OPEN position.
6. Close the exhaust valve.
7. Open the turbine casing drains.
8. Secure the supply of cooling water to the lube oil cooler.
9. Close the turbine casing drains after all condensate has drained and the turbine casing has cooled to room temperature.
10. Close the steam root valve, so that steam will not bleed into the turbine casing.

TESTS AND INSPECTIONS

At very short intervals during each watch, check the bearings, oil flow sights, and all pressure and temperature gages on all operating auxiliary turbines. Listen for sounds which would indicate damaged or defective bearings. At least once during each watch, operate the speed-limiting or speed-reg-

ulating governor valve stem by hand. CAUTION: When operating the governor valve stem, be careful not to overspeed the unit.

The following tests and inspections must be performed DAILY on idle turbines, and appropriate entries made in the log or check-off list:

1. Turn idle turbines by hand.
2. If a hand pump is provided, use it to circulate oil through the lubrication system of each idle turbine.

The following tests and inspections must be made WEEKLY, and the results entered in the appropriate check-off list or log:

1. Inspect the valves, cocks, and joints of steam, exhaust, and drain lines.
2. Operate all valves not in use; and oil the valve stems if necessary.
3. If an overspeed trip is installed, lubricate the linkage.
4. Run the turbine with steam, if practicable.
5. Test the overspeed trip by overspeeding the unit.
6. Operate the turbine casing relief valve by hand.

The following tests and inspections must be made QUARTERLY, and appropriate entries made in the log or check-off list:

1. Test the speed-limiting governor. (This must also be done whenever a turbine is put back into service after prolonged idleness, and whenever the speed-limiting governor has been dismantled for any reason.)
2. Examine the interior of the casing, if possible. (Peepholes are provided on many auxiliary turbines.) Inspect the exterior of the casing for evidence of corrosion.
3. Sound the casing with a hammer, to detect cracks.
4. Examine the casing for loose or broken bolts.
5. Check the setting of the turbine casing relief valve.
6. Clean the steam strainers.
7. Check the shoes of the thrust bearing for clearance and for the condition of the bearing surface.

8. After examining the thrust bearing, blow through it with clean air.
9. Check all sleeve-type bearings for clearances and for the condition of the journal and bearing surfaces.
10. Check the calibration of all gages.

The following tests and inspections must be made EVERY SIX MONTHS, and the results entered in the appropriate check-off list or log:

1. Check the condition of the carbon and labyrinth packing.
2. Open, examine, and clean all ball bearings.

The following tests and inspections must be made ANNUALLY, and the results entered in the appropriate check-off list or log:

1. Open the turbine and reduction gear casings for inspection and cleaning.
2. Examine the turbine rotor, the blading, the shaft, all bearings, and the reduction gears.

SAFETY PRECAUTIONS

The following safety precautions must be observed by all personnel concerned with the operation of auxiliary turbines:

1. Always turn the turbine rotor by hand before admitting steam to the casing.
2. Never lash down an overspeed trip, a speed-limiting governor, or a speed-regulating governor. Do not in any way attempt to render these safety devices inoperable.
3. Be sure that the turbine casing relief valve is set to lift at the proper pressure, and that it is operable at all times.
4. Before starting a turbine, be sure that it is free of foreign objects.
5. Always test the overspeed trip (if installed) when putting a turbine into service.

6. Never start up an auxiliary turbine before it and the steam inlet piping are properly drained. Turbine casualties and serious injury to personnel have resulted from inadequate drainage of steam inlet lines which allowed large slugs of water to be carried over with the steam.

MANUFACTURERS' INSTRUCTION BOOKS

Instructions for the operation, care, and repair of each auxiliary turbine are found in the manufacturer's instruction book which is furnished with each machine. Since auxiliary turbines vary greatly in design and construction, the instructions for operating and maintaining them cannot be standardized. The information given in this chapter should be considered as general, rather than specific, in nature; and it must be supplemented by reference to the appropriate manufacturer's instruction book. NEVER attempt to operate or repair any auxiliary turbine without having a thorough understanding of the manufacturer's instructions for that particular machine.

QUIZ

1. In an impulse turbine, what term is used to describe one set of nozzles and its succeeding row or rows of moving and fixed blades?
2. In what part or parts of an impulse turbine does a pressure drop occur?
3. What is a Rateau stage?
4. An impulse turbine has one set of nozzles, but two rows of blades on the rotor. How would you classify this turbine with respect to staging and compounding?
5. What name is usually given to a single velocity-compounded stage in a single-entry turbine?
6. In what two ways are impulse turbines velocity-compounded?
7. What is a pressure-compounded turbine?
8. What is the advantage of having equal pressure on both sides of an impulse turbine?
9. Why is it necessary to use thrust bearings on impulse turbines?
10. What purpose is served by shaft glands?
11. What two types of packing are used in turbine shaft glands?
12. What is the advantage of using reduction gears between a turbine and a turbine-driven auxiliary?
13. What devices are used to take care of very slight misalinement between driving turbines and their driven auxiliaries?
14. At what speed does a speed-limiting governor begin to control the admission of steam to the steam chest?
15. What parts of an auxiliary turbine are NOT lubricated by the pressure lubrication system, and must therefore be lubricated separately?

CHAPTER 6

PUMPS

Pumps are used to move any substance which flows or which can be made to flow. When we think of pumping, we ordinarily think of moving water, oil, air, steam, and other common liquids and gases. However, such substances as molten metal, sludge, and mud are also fluid and can be moved with pumps.

Pumps are so widely used, for such varied services, that the number of different designs is almost overwhelming. As a general rule, however, you can remember that all pumps are designed to move fluid substances from one point to another by pulling, pushing, or throwing, or by some combination of these three methods.

You should remember, also, that no matter how complicated a pump looks it must have a POWER END and a FLUID END. The power end may be a steam turbine, a reciprocating steam engine, a steam jet, or an electric motor. In steam-driven pumps, the power end is often called the STEAM END. The fluid end is generally called the PUMP END; however, it may be called the LIQUID END, the WATER END, the OIL END, the GAS END, etc., to indicate the nature of the fluid substance being pumped.

On board ship, pumps are used for a number of essential services. Pumps feed water to the boilers, draw condensate from the condensers, supply sea water to the firemain, circulate cooling water for coolers and condensers, empty the

bilges, transfer fuel oil, discharge fuel oil to the burners, and serve many other purposes. The operation of the ship's propulsion plant and of almost all auxiliary machinery depends upon the proper operation of pumps. Pump failure may cause failure of an entire power plant.

As a Boilerman, you will be required to know something about the operation and maintenance of the fireroom pumps which are discussed in this chapter. Before studying this chapter, however, you should have at your command a general knowledge of the basic operating principles of various types of pumps. You may find it helpful to review this subject in *Fireman*, NavPers 10520–A. In addition, you will find it necessary to refer to the chapter in this training course on auxiliary turbines, since many of the pumps to be described here are driven by steam turbines. In this chapter we will deal only with reciprocating pumps, variable stroke pumps, rotary pumps, and centrifugal pumps, because these are the types you will most frequently find in the fireroom. For information on other types of pumps, you should consult *Fireman;* BuShips *Manual*, Chapter 47; and appropriate manufacturers' instruction books.

RECIPROCATING PUMPS

The reciprocating pump moves water or other liquid by means of a plunger which reciprocates—that is, goes back and forth or up and down—within a cylinder. Reciprocating pumps are usually classified as:

1. Direct- or indirect-acting
2. Simplex (single) or duplex (double)
3. Single-acting or double-acting
4. High-pressure or low-pressure
5. Vertical or horizontal

The reciprocating pump shown in figure 6–1 is a direct-acting, simplex, double-acting, high-pressure, vertical pump. Now let's see what all these terms mean, with reference to the pump shown in the illustration.

The pump is DIRECT-ACTING because the pump rod is a

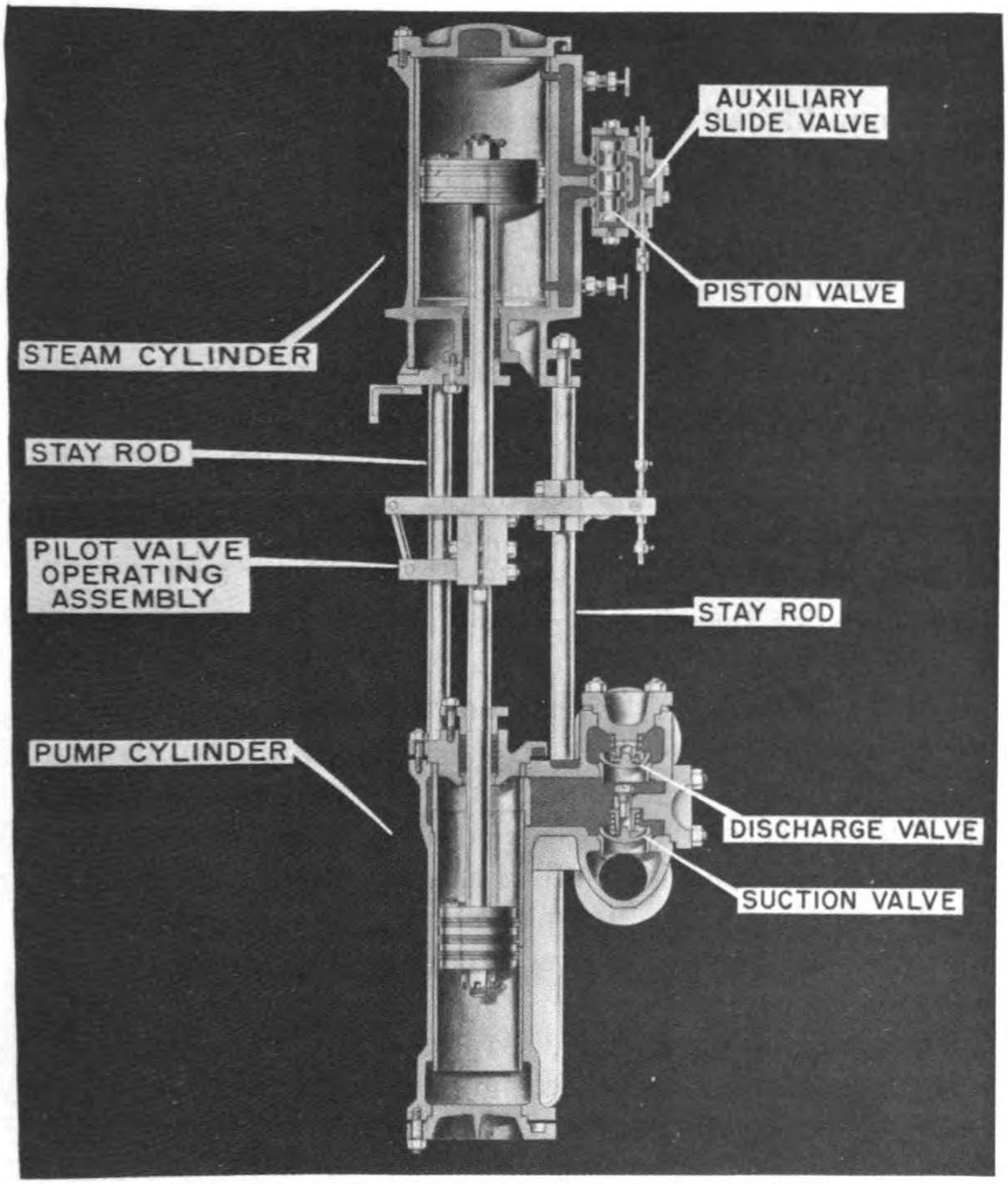


Figure 6–1.—Reciprocating pump.

DIRECT extension of the piston rod; and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct-acting. An INDIRECT-ACTING pump may be driven by means of a beam or linkage which is connected to and motivated by the steam piston rod in a separate reciprocating engine; or it may be driven by a crank-and-connecting rod mechanism which is operated by a steam turbine or an electric

motor. An indirect-acting pump might appear to have only one end—that is, the pump end. However, don't forget that this pump, like all others, must have a power end as well. The separate engine, turbine, or motor which drives the pump is the actual power end of the pump.

The pump shown in figure 6–1 is called a SINGLE or SIMPLEX pump because it has only one liquid cylinder. Simplex pumps may be either direct-acting or indirect-acting. A DOUBLE or DUPLEX pump is an assembly of two single pumps, placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. Duplex reciprocating pumps are seldom found in modern combatant vessels, but were commonly used in older ships.

In a SINGLE-ACTING pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a DOUBLE-ACTING pump, each stroke serves both to draw in liquid and to discharge liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end which was just emptied is filled and the end which was just filled is emptied. The pump shown in figure 6–1 is double-acting, as are most of the reciprocating pumps used in the Navy.

The pump shown in figure 6–1 is designed to operate with a discharge pressure which is higher than the pressure of the steam operating the piston in the steam cylinder. In other words, this is a HIGH-PRESSURE pump. In a high-pressure pump, the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder; and, therefore, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against a high pressure. A LOW-PRESSURE pump, on the other hand, has a comparatively low

discharge pressure but a larger volume of discharge. In a low-pressure pump, of course, the steam piston is smaller than the plunger in the liquid cylinder.

The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order: (1) the diameter of the steam piston; (2) the diameter of the pump plunger; and (3) the length of the stroke. For example, a 12″ x 11″ x 18″ reciprocating pump has a steam piston which is 12 inches in diameter, a pump plunger which is 11 inches in diameter, and a stroke of 18 inches. As you can see, the designation enables you to tell immediately whether the pump is a high pressure or low pressure pump.

Finally, the pump shown in figure 6–1 is classified as VERTICAL because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; but you may occasionally encounter a HORIZONTAL pump, in which the piston moves back and forth rather than up and down.

The following discussion of reciprocating pumps is generally concerned with direct-acting, simplex, double-acting, vertical pumps, since most reciprocating pumps used in the Navy are of this type.

Construction of Reciprocating Pumps

The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder, so that water resulting from condensation may be drained off.

Some reciprocating pumps have cushioning valves at each end of the steam cylinder. These valves can be adjusted to trap a certain amount of steam at the end of the cylinder; thus, when the piston reaches the end of its stroke, it is cushioned by the steam and prevented from hitting the end of the cylinder. When the pump is operating at high speeds,

the cushioning valves should be nearly closed so that a considerable amount of steam will be trapped at each end of the cylinder; at low speeds, the cushioning valves should be almost open. (The steam cylinder shown in figure 6–2 does not have cushioning valves.)

Automatic timing of the admission and release of steam to and from each end of the steam cylinder is accomplished by various types of valve arrangements. Figure 6–2 shows the piston-type valve gear commonly used for this purpose; it consists of a main piston-type slide valve and a pilot slide

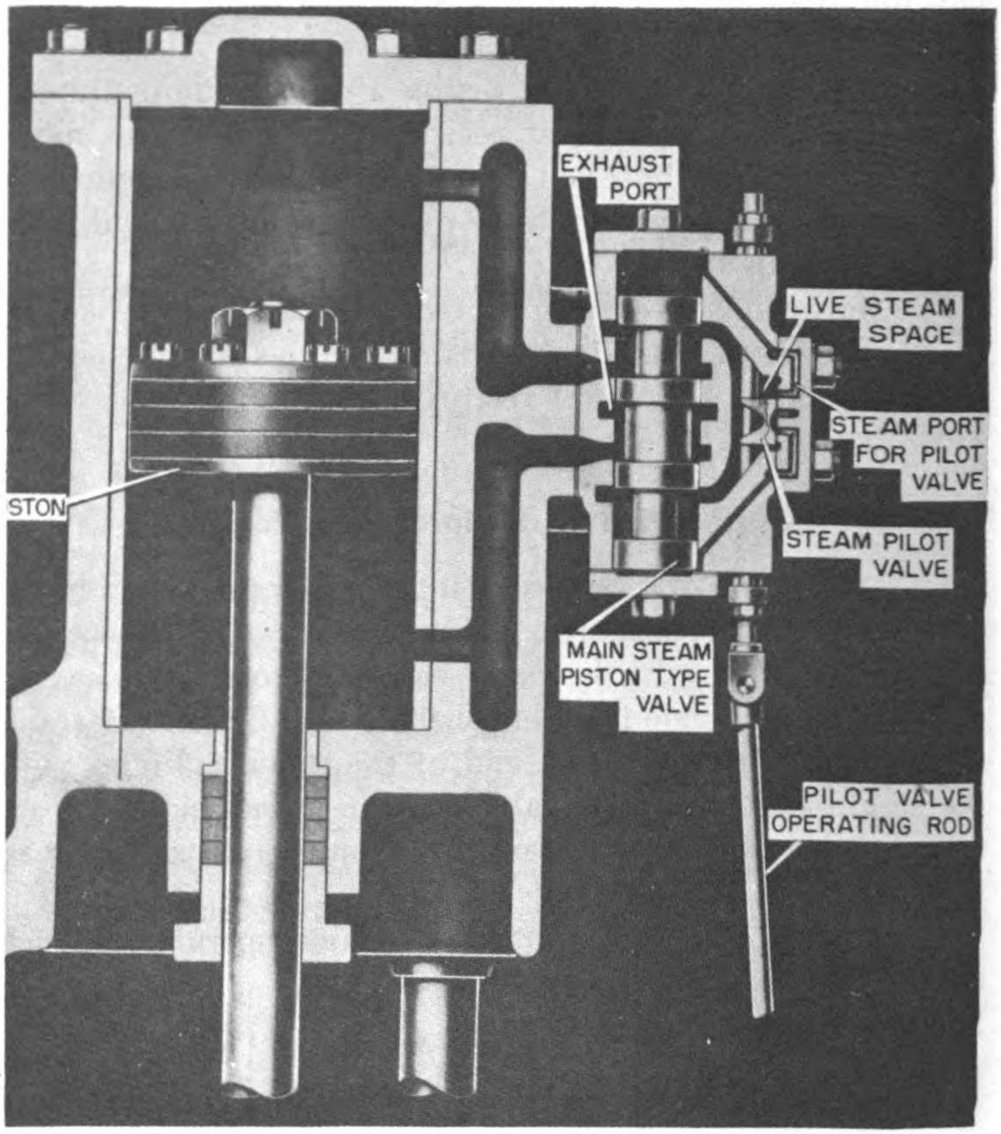


Figure 6–2.—Piston-type valve gear for steam end of reciprocating pump.

valve. Since the rod from the pilot valve is connected to the pump rod by a valve-operating assembly, the position of the pilot valve is controlled by the position of the piston in the steam cylinder. The pilot valve furnishes actuating steam to the main piston-type valve, which, in turn, admits steam to the top or the bottom of the steam cylinder at the proper time.

The valve-operating assembly which connects the pilot valve operating rod and the pump rod is shown in figure 6–3. As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the

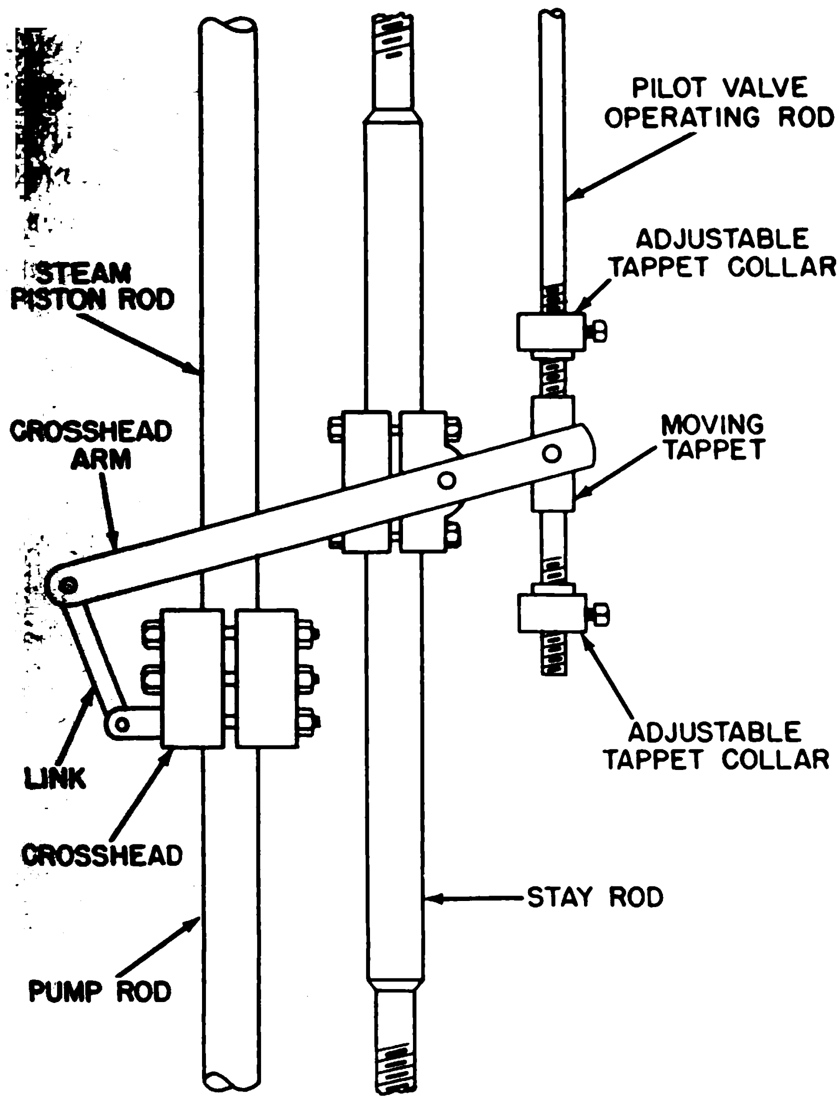


Figure 6–3.—Valve-operating assembly.

moving tappet slides up and down on the pilot valve operating rod. The tappet collars are adjusted so that the pump will make the full designed stroke.

The liquid end of a reciprocating pump has a piston and cylinder assembly similar to that of the power or steam end. The piston in the liquid end is often called a PLUNGER. A VALVE CHEST, sometimes called a WATER CHEST, is attached to the liquid cylinder; it contains two sets of suction and discharge valves, one set to serve the upper end of the liquid cylinder and one to serve the lower end. The valves are so arranged that the pump takes suction from the suction chamber and discharges through the discharge chamber on both the up and down strokes.

An adjustable relief valve is fitted to the discharge chamber, to protect the pump and the piping against excessive pressure.

Some reciprocating pumps have an air chamber and a snifter valve installed in the liquid end. The upper part of the air chamber contains air; the lower part contains liquid. On each stroke, the air in the chamber is compressed by the pressure exerted by the plunger. When the plunger stops at the end of a stroke, the air in the chamber expands and allows a gradual, rather than sudden, drop in the discharge pressure. The air chamber, therefore, smooths out the discharge flow, absorbs shock, and prevents pounding. The snifter valve, if installed, allows a small quantity of air to be drawn in and compressed with each stroke. If no snifter valve is installed, some provision is usually made for charging the air chamber with compressed air.

Fireroom Applications

Reciprocating pumps are used for two main purposes in the fireroom: (1) as fire and bilge pumps; and (2) as emergency or auxiliary feed pumps. Reciprocating pumps are very good for emergency use because they are relatively simple, reliable, and easy to start and operate under cold conditions.

The FIRE AND BILGE PUMP is sometimes called the STANDBY FIRE PUMP. In emergency, it is used as a fire-and-flushing pump. The fire and bilge pump is designed to operate on relatively low-pressure steam (usually about 150 psi or a little higher). Although the steam piston is slightly larger in diameter than the water piston, this pump is usually thought of as a low-pressure pump because its discharge pressure is lower than the pressure of the steam which operates the piston in the steam cylinder, WHEN THE PUMP IS OPERATING AT FULL CAPACITY. The reason for this apparent contradiction—that is, a low-pressure pump in which the steam piston is larger in diameter than the water plunger—lies in the fact that this pump is designed to discharge a large volume of water very rapidly. At full capacity, therefore, extra steam pressure is required to overcome the losses from friction which result from the very high rate of discharge. When the pump is operating slowly, the discharge pressure is slightly higher than the steam pressure; and the pump might, in this condition, be thought of as a high-pressure pump.

Procedures for the operation, maintenance, and repair of the fire and bilge pump are, in general, the same as for any other reciprocating pump. With the fire and bilge pump, however, special precautions must be taken to see that the suction strainers are kept clean. Clogged suction strainers and the presence of foreign matter in the water chest suction and discharge valves are the most frequent causes of trouble in the liquid end of the fire and bilge pump.

The EMERGENCY OR AUXILIARY FEED PUMP is a direct-acting, simplex, double-acting, high-pressure, vertical pump of the type shown in figure 6–1. The pump is operated from the auxiliary steam line. It is used for filling idle boilers, for transferring reserve feed water, for applying pressure to boilers undergoing hydrostatic test, and in some cases for regular boiler feed service for in-port (auxiliary) steaming. This pump does not have sufficient capacity for high firing rates, and its use is therefore limited to emergency or auxiliary service.

It should be noted that the main feed pump is almost always of the centrifugal type which requires a positive suction head. If the feed booster pumps fail, or if the deaerating feed tank goes dry, therefore, the main feed pump cannot take suction from the reserve feed tanks, since these are usually located below pump level. Reciprocating pumps, on the other hand, do not require a positive suction head, and are therefore capable of taking suction from reserve feed tanks. It is primarily for this reason that all emergency feed pumps are of the reciprocating type.

The emergency or auxiliary feed pump must be kept in a standby condition whenever the fireroom is steaming. To keep the pump in standby condition, it is necessary to keep the pump idling slowly with the recirculating valve open, and with suction lined up to the reserve feed tank. Some emergency feed pumps are provided with a discharge check valve so that the discharge valve may also be kept open while the pump is in standby condition.

When an emergency feed pump is used for in-port steaming, another pump must always be used for standby. This precaution is necessary in order to avoid a serious engineering casualty, in the event of failure of the emergency feed pump. (In other words, don't ever depend on only one pump to supply water to the boiler—always have another pump in standby condition.)

The emergency feed pump is also used to add boiler compound to the water in the boiler, and an open suction connection is provided for this purpose. After the compound has been taken in, enough additional water must be pumped to ensure that all the boiler compound is carried through the pump and the lines to the boiler. CAUTION: If the emergency feed pump has been taking a hot suction, it must be cooled down before it is used to pump boiler compound into the boiler.

It should be noted that the emergency or auxiliary feed pump does NOT have an air chamber or a snifter valve. These devices are not suitable for a feed pump, since they would tend to draw air into the feed water.

Operation of Reciprocating Pumps

The general procedure for starting a reciprocating pump is as follows:

1. Check to be sure that the steam cylinder and steam chest drain valves are open. (They should always be opened when the pump is shut down.)
2. Oil the pins of the steam valve operating gear; and set up on any grease cups which may be fitted. (Some modern reciprocating pumps do not have grease cups.)
3. Open the liquid end suction and discharge valves.
4. Open the exhaust and steam line root valves (if installed).
5. Open the steam exhaust valve (cut-out valve) at the pump.
6. Crack open the steam throttle valve and admit steam SLOWLY so that the steam cylinder will warm up gradually.
7. Close the steam cylinder drains after the pump has made a few strokes. Do not close these drains until the steam cylinder is clear of water.
8. Open the throttle valve slowly to bring the pump up to the desired operating speed or discharge pressure.
9. Follow any additional instructions indicated by experience with a particular design of pump or laid down by the engineering officer.

In general, the steps to be followed in stopping and securing a reciprocating pump are:

1. Close the steam throttle valve.
2. Close the steam exhaust valve at the pump.
3. Open the steam cylinder drains.
4. Close the liquid end suction and discharge valves.
5. Close the steam and exhaust root valves.

Sometimes you will find that the pump won't kick over when you line it up and crack open the throttle valve. You may open the throttle a little wider, but still nothing happens. You go through the whole starting procedure again, to make

sure that everything has been done correctly—but still the pump will not run. At this point, proceed as follows:

1. Secure the pump.
2. Examine the discharge line and the exhaust line. The trouble may be a closed valve, or a valve in which the disk has become detached from the stem.
3. Check the rod packing glands at the steam end and at the water end; if someone has set up on them too tightly, the pump may be locked so that it cannot move.
4. If the trouble cannot be located by any of the above measures, report the fact to the proper authority.

From time to time you are likely to have some operating troubles with reciprocating pumps. Some of the most common causes of trouble, together with their symptoms and remedies, are described here.

Lack of proper suction will cause jerky or irregular operation of the pump, or it may cause the pump to race without any appreciable increase in discharge pressure. Loss of suction may be caused by a number of different conditions, including:

1. Obstructions in the suction line.
2. Loss of suction head, which causes the pump to become vapor-bound.
3. Air in the system, which causes the pump to become air-bound.

Obstructions in the suction line frequently cause trouble in the case of fire and bilge pumps. Be sure that the suction line is clear and that all stop or check valves in the line are open. Clean the suction line strainer and the bilge strainer.

The emergency feed pump is particularly likely to become vapor-bound due to loss of suction head. If this occurs, and a standby pump is not available, you will have to cool the pump rapidly. Shift to cold water suction—that is, shift to a reserve feed tank. Open the vents on the liquid end valve chest. Cool the pump by turning a hose on it, or by pouring buckets of cold water over it. Continue cooling measures until you see a steady flow of water com-

ing from the vents. Continue feeding cold water until the head pressure is restored.

A pump can lose suction by becoming air-bound—that is, having air trapped in the system. The remedy for this condition is to open the aircocks and vents on the liquid end valve chest; leave them open until water flows out.

Insufficient prime often causes loss of suction in pumps which have a considerable suction lift. The fire and bilge pump can usually be primed from the sea by opening the sea suction valve for a short time.

Worn packing on the plunger or damaged suction or discharge valves in the liquid end may cause the pump to race without an appreciable increase in discharge pressure. It is hard to distinguish this kind of trouble from the troubles caused by loss of suction, since the general symptoms are very similar. However, if you suspect that the plunger packing is worn or that the liquid end valves are damaged, you should stop the pump as soon as possible and locate and correct the trouble.

Groaning in the steam end of the pump may indicate that the packing is too tight, that the piston or a piston ring is broken, that rust has formed in the cylinder, or that the steam cylinder is out of alinement. The pump should be secured so that the difficulty may be found and corrected.

Groaning in the liquid end of the pump is generally due to excessively tight packing or a broken or damaged follower plate or other broken parts. Stop the pump and investigate.

Knocking in the steam end of the pump may be caused by too long a stroke, by water in the steam cylinder, by loose piston rings, or by some difficulty in the piston-type valve gear. The pump should be stopped at once so that the trouble may be found and corrected.

Proper adjustment of the length of stroke is extremely important. If the stroke is too long, the steam piston will hit against the cylinder heads and make a heavy, metallic, knocking sound. When the stroke is too short, the pilot valve may block the ports sufficiently to interfere with the

admission of steam to the main valve; and this may cause the pump to stop. In addition, a short stroke causes shoulders to be worn in the cylinder; and when the stroke is lengthened, these shoulders may cause the piston rings to break. Improper length of stroke, whether too short or too long, may cause great damage to the pump. Secure the pump immediately, and adjust the stroke as necessary.

Maintenance and Repair

Reciprocating pumps require a certain amount of routine maintenance and, upon occasion, some repair work. Some of the most important points of maintenance and repair are mentioned here. For further information you should consult chapter 47 of BuShips *Manual*, and the applicable manufacturers' instruction books.

All moving parts of the valve-operating assembly should be kept well oiled. However, you must NOT attempt to lubricate the internal parts of the steam end or of the liquid end of the pump. A slight gland leak-off is sufficient to lubricate the pump rod. Do not use oil on the pump rod.

Piston rod packing should be renewed whenever it becomes worn or dried out. A little routine maintenance here can save you a good deal of work, since it is much easier to renew packing than it is to replace rods.

Stroke adjustment is very important. Be sure that the pump is making a full stroke. The piston should travel a little beyond the top and bottom counterbore. The position of the piston in relation to the top counterbore is shown in figure 6–4.

A stroke indicator is usually provided on reciprocating pumps, as an aid in checking the length of stroke. The indicator consists of a pointer secured to the piston rod crosshead, and two marks on one of the cylinder tie rods. The upper mark should line up with the pointer on the crosshead when the piston is at the upper end of the stroke; the lower mark should line up with the pointer when the piston is at the lower end of the stroke.

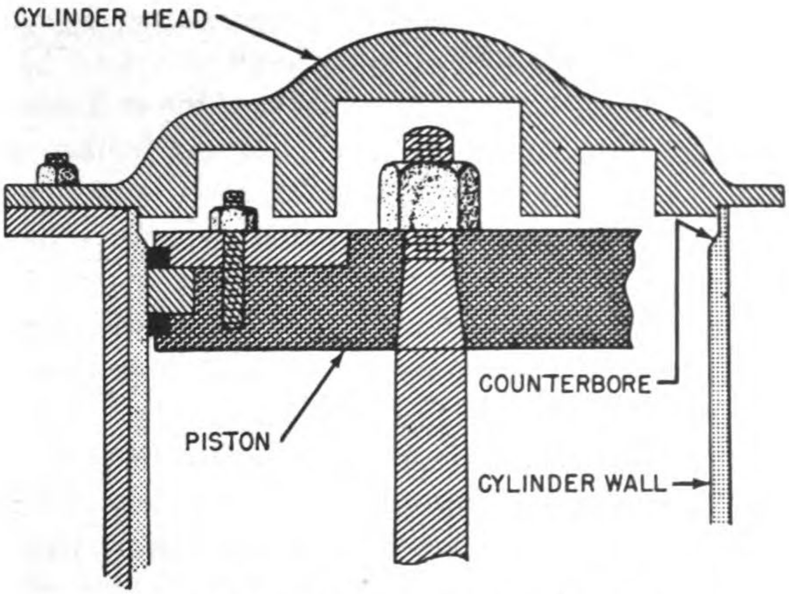


Figure 6–4.—Piston at upper end of stroke.

Length of stroke is adjusted by changing the setting of the tappet collars on the pilot valve operating rod. You may have to secure the pump in order to set the tappet collars; but final adjustment of the stroke must be made while the pump is operating. To shorten the stroke, the tappet collars are moved closer together; to lengthen the stroke, they are moved farther apart. The tappet collars should not be moved unless absolutely necessary. If frequent adjustment of the collars appears to be required, something else is wrong with the pump.

Salt water pumps require special maintenance measures because of the danger of corrosion. About once every 6 months the internal parts of the liquid end should be examined and cleaned. If zincs are installed, they should be inspected once a month and replaced when necessary. (The use and replacement of zincs will be discussed in the chapter on maintenance and repair.)

Before you begin to repair a reciprocating pump, assemble all the pertinent blueprints and drawings; these will give you clearances, measurements, information regarding materials to be used, and other important information. You should also have the complete history of the pump you are repairing, so that you will know what has been done before,

when it was done, what kind of trouble has been encountered with this particular pump, and so forth.

Most reciprocating pump troubles are due to fouled water cylinders, worn or broken valves, loose or broken plunger followers, worn plunger packing, and scored water cylinders. Therefore, the logical place to start a pump overhaul is in the liquid end.

First of all, you must be sure that all valves in the lines leading to and from the pump are secured, wired closed, and tagged.

Drain the pump end by opening the drain valves in the bottom of the valve chest and water cylinder. If there is enough room below the water cylinder to allow you to take the plunger and rod out through the bottom, you should:

1. Disconnect and remove the crosshead arm from the crosshead.
2. Take off the crosshead. CAUTION: Mark the exact position of the crosshead on both the pump rod and the steam piston rod, so that you will have reference points for reassembling the crosshead. In reassembly, each rod MUST be placed in the crosshead exactly as it was originally.
3. Free the packing gland and remove the packing.
4. Remove the top cylinder head and loosen the nuts on the follower plate. CAUTION: Before removing either cylinder head, be sure to put mating marks on both the head flange and the cylinder flange. There is less likelihood of leakage, when the pump is reassembled, if the flange faces match up exactly.
5. Remove the bottom cylinder head (observing the precaution just mentioned) and take the plunger and rod out through the bottom of the water cylinder.

If it is possible to take the plunger and rod out through the bottom of the water cylinder, repair work on the water end of the pump will be relatively easy. Frequently, however, you will find that lack of space below the water cylinder makes it impossible to get at the pump from the bottom. In this event, do not disassemble the crosshead. Leave the

plunger rod connected to the steam piston rod. Raise the crosshead to its top position, and fasten it securely. (If the crosshead is not held up properly, the entire reciprocating assembly will drop down when the packing gland and the follower plate are loosened.)

Free the packing gland, and remove the packing; then move the top cylinder head and the follower plate up to the crosshead. Remove the old packing from the plunger, and fit new packing rings. If spacer rings are fitted, they must be moved up toward the crosshead as the packing is removed; then, after each new packing ring is fitted, a spacer ring must be brought down into the cylinder again.

If possible, packing should be placed in boiling water and soaked for at least 12 hours before it is used for repacking plungers. In emergencies, however, when there is no time for soaking, dry packing may be used if it is cut with enough clearance to allow for swelling. Each packing ring should be cut with a step gap, and the gaps should be staggered when the plunger is assembled. CAUTION: Different types of packing are required for different types of pumps. Be sure you get the proper kind of plunger packing for the particular job you are doing.

An inside micrometer should be used to check the measurements of the water cylinder, after the plunger has been removed. If the cylinder is burred or scored, it must be smoothed by stoning. Water cylinders should not be rebored or relined unless they are in very bad condition.

Badly worn or enlarged throat bushings should be renewed when the pump is being overhauled. Undersize follower plates and plunger pistons should be built up by gas or electric welding, and then turned to size on a lathe.

Flange surfaces should be cleaned and smoothed before the pump is reassembled; and gaskets should be renewed. When renewing gaskets, be sure to use material of the proper kind and correct thickness.

Figure 6–5 illustrates the general arrangement of valves in the water chest. On the fire and bilge pump, access to the

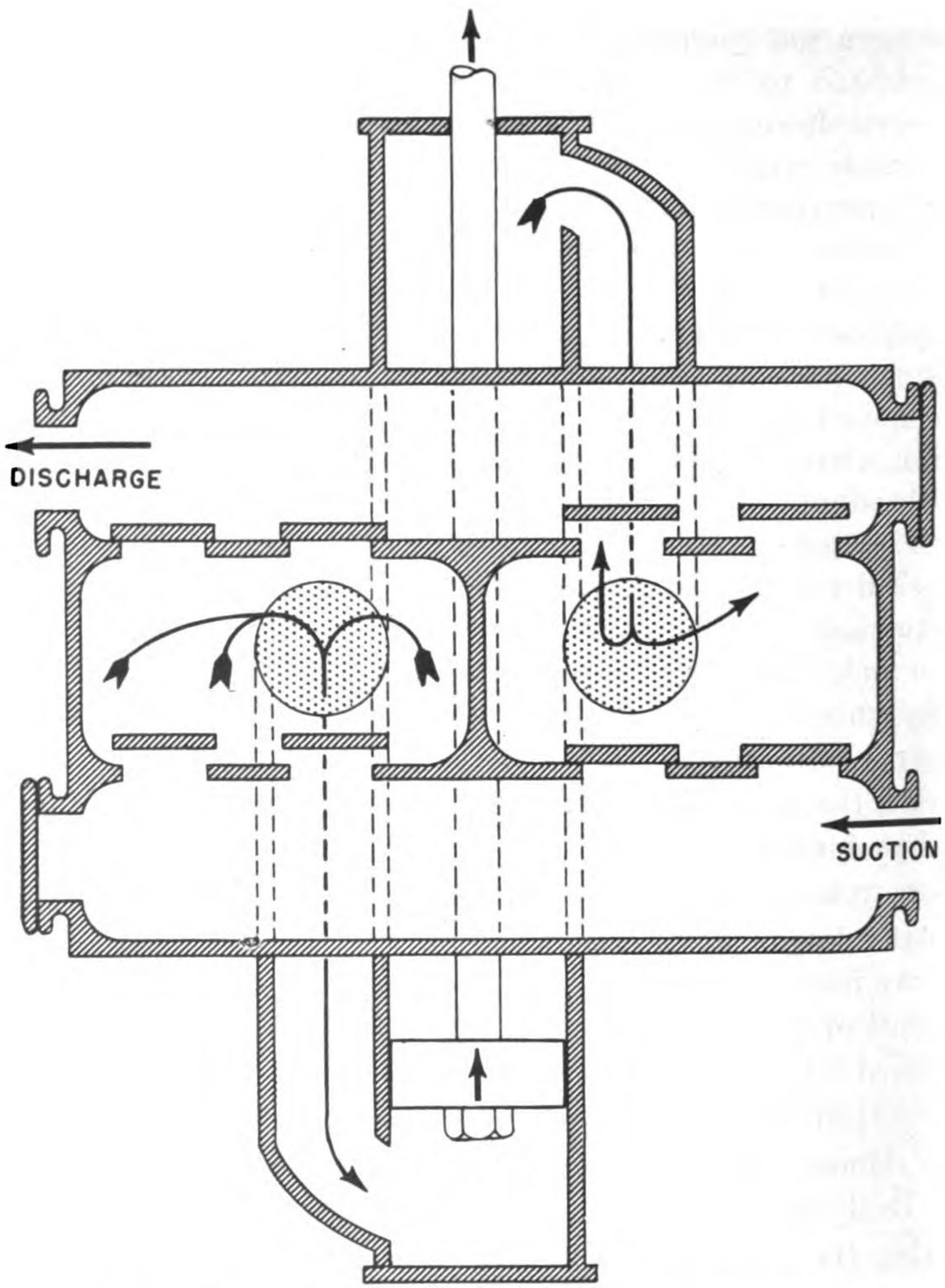


Figure 6–5.—General arrangement of valves in water chest.

water chest valves is usually through a front cover plate; on the emergency feed pump, removal of a top cover plate allows you to get at the valves.

In some arrangements, the valves seat on the valve plate itself. In other arrangements, the valve plate is a part of

the casting, and the valve seats are screwed into it or, in some cases, force fit—that is, the opening in the valve plate is a few thousandths of an inch SMALLER than the valve seat, so the valve seat must be pressed or forced into place. When removing and replacing screwed or force fit valve seats, special precautions should be taken to prevent warping.

As you remove the suction and discharge valves from the water chest, be sure to put all parts into a suitable container so that later you won't have to hunt for misplaced parts. Valves, seats, stems, and springs should be marked before removal, so that you will be able to match them in sets for proper assembly.

Valve seats should be inspected carefully. Scored or pitted valve seats and disks should be ground in. Broken or worn valve cages, stems, springs, and binding screws should be renewed.

You will probably not be required to do much work on the steam end of a reciprocating pump. However, you should be able to make some repairs to the valve gear which controls the admission and release of steam to and from the steam cylinder. As mentioned before, various types of valve arrangements are used for this purpose. On some pumps, for example, one flat D-type slide valve performs the whole job; on others, you will find a steam-thrown flat main valve and a flat auxiliary or pilot valve; on others, a piston-type main valve and a flat pilot valve; and on still others, a piston-type main valve and a piston-type pilot valve.

The flat D-type slide valve and its seating surfaces should be ground in or faced off so that the valve will make a smooth, tight fit. Auxiliary pistons and piston-type valves are generally fitted with rings which may require renewal.

Tests

The following tests should be conducted on reciprocating pumps:

1. Jack over all idle pumps by hand DAILY.
2. Move all pumps by steam or power WEEKLY.

3. Inspect liquid end valves, valve stems, and springs; inspect steam valve gear for wear; and check setting of relief valves QUARTERLY.

Safety Precautions

The following safety precautions concerning reciprocating pumps have been specified by the Bureau of Ships:

1. Never attempt to jack over a pump while the steam valve to the pump is open.
2. Do not use the emergency or auxiliary feed pump for purposes other than those connected with the service of boilers or the use of feed water, except in emergency.
3. Before opening a steam cylinder or a steam chest, be sure that all drains are open and that the steam and exhaust root valves are wired closed.
4. Before opening the water cylinder or the valve chest of a pump handling water at a temperature in excess of 120° F, be sure that the suction and discharge valves are wired closed, and that the cylinder and the valve chest are drained.
5. Always open the steam cylinder drain valves and the steam chest drain valves when the pump is shut down, and leave them open until the pump is again in operation and has been cleared of condensate.

VARIABLE STROKE PUMPS

Variable stroke pumps are used on many vessels as in-port or cruising fuel oil service pumps. Although they are often classified as rotary pumps, they are actually reciprocating pumps. A rotary motion is imparted to the pump by a constant-speed electric motor, but the actual pumping is done by a set of pistons reciprocating inside a set of cylinders. The means by which the rotary motion is translated into reciprocating motion is described and illustrated in *Fireman*, NavPers 10520–A.

There are two general types of variable stroke pumps in common use. In the axial-piston type, the pistons are ar-

ranged parallel to each other and to the pump shaft; in the radial-piston type, the pistons are arranged radially from the shaft.

The AXIAL-PISTON VARIABLE STROKE PUMP, shown in figure 6–6, usually has either seven or nine single-acting pistons which are evenly spaced around a cylinder barrel. (Note that the term CYLINDER BARREL, as used in this connection, actually refers to a cylinder BLOCK which holds all the cylinders.) The piston rods make a ball-and-socket connection with a socket ring. The socket ring rides on a thrust bearing

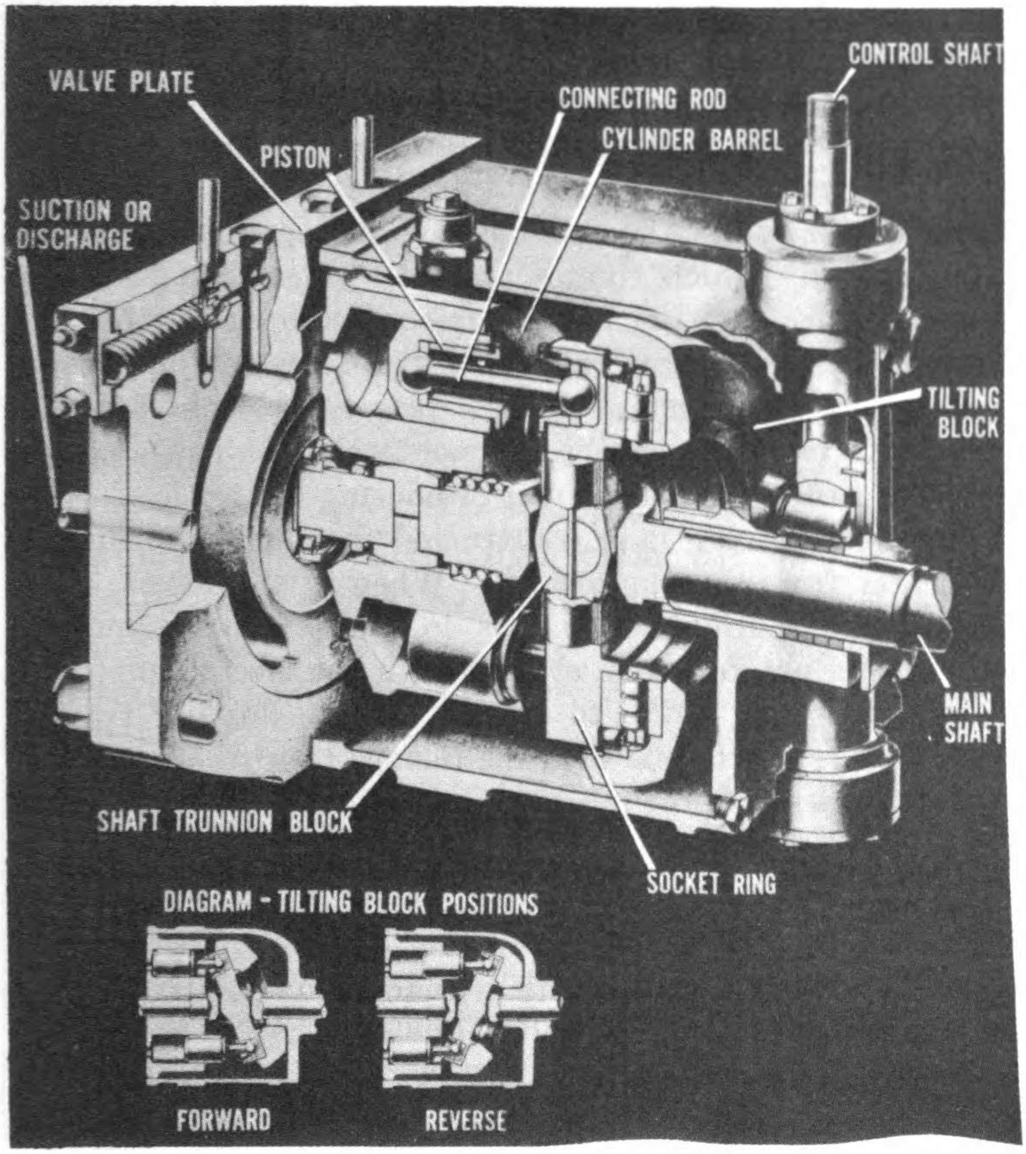


Figure 6–6.—Axial-piston variable stroke pump.

carried by a casting called the TILTING BOX or TILTING BLOCK.

When the tilting box is at a right angle to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping takes place. When the box is tilted away from a right angle, however, the pistons reciprocate and the liquid is pumped.

If the tilting box is designed to be moved in only one direction, the liquid can flow in only one direction. In some pumps, however, the tilting box is so arranged that it may be tilted in either direction, thus allowing the liquid to be pumped in either direction. As you can see, the position of the tilting box controls both the direction of flow and the amount of flow.

The RADIAL-PISTON VARIABLE STROKE PUMP is similar in general principle to the axial-piston type just described, but the arrangement of component parts is different. In the radial-piston pump, the cylinders are arranged radially in a cylinder body which rotates around a nonrotating central cylindrical valve. Each cylinder communicates with horizontal ports in the central cylindrical valve. Plungers or pistons, which extend outward from each cylinder, are pinned at their outer ends to slippers which slide around the inside of a rotating floating ring or housing.

The floating ring is so constructed that it can be shifted off center from the pump shaft. When it is centered, or in the neutral position, the pistons do not reciprocate and the pump does not function, even though the electric motor is still causing the pump to rotate. If the floating ring is forced off center to one side, the pistons reciprocate and the pump operates. If the floating ring is forced off center to the other side of the pump shaft, the pump also operates but the direction of flow is reversed. Thus it can be seen that the direction of flow and the amount of flow are both determined by the position of the cylinder body relative to the position of the floating ring.

When used for fuel oil service, variable stroke pumps are designed to be nonreversing. They operate at constant speed, with a constant discharge pressure, but with varying ca-

pacity. Spring tension is often used to control the position of the tilting box or of the floating ring, and so to maintain constant pressure while varying the amount of liquid which is pumped. When this type of constant pressure control is fitted, it is usually adjustable from 150 to 300 psi. Most variable stroke pumps have, in addition, a hand-operated capacity control device which can be used instead of the spring tension to adjust the capacity of the pump.

ROTARY PUMPS

All rotary pumps work by means of rotating parts which trap the liquid at the suction side and force it through the discharge outlet. Gears, screws, lobes, vanes, and cam-and-plunger arrangements are commonly used as the rotating elements in rotary pumps. Rotary pumps, like reciprocating pumps, operate on the positive-displacement principle—that is, each rotation or each stroke delivers a definite quantity of liquid.

Rotary pumps are particularly useful for pumping oil and other heavy, viscous liquids. In the fireroom this type of pump is used for fuel oil service, fuel oil transfer, and lubricating oil service. Rotary pumps are also used for nonviscous liquids, such as water or gasoline, where the pumping problem involves a high suction lift.

The power end of a rotary pump is usually an electric motor or a steam-driven turbine. The main fuel oil service and transfer pumps are generally steam-driven. A smaller fuel oil service pump driven by an electric motor is often used for in-port steaming or for steaming at low firing rates. In addition, most firerooms have a hand-driven fuel oil service pump which can be used either for lighting off boilers in a completely cold plant or for emergency fuel oil service in the event of complete power failure of the ship. A hand-driven fuel oil service pump is shown in figure 6–7.

Rotary pumps are designed with very small clearances between rotating parts, and between rotating parts and stationary parts, in order to minimize slippage from the dis-

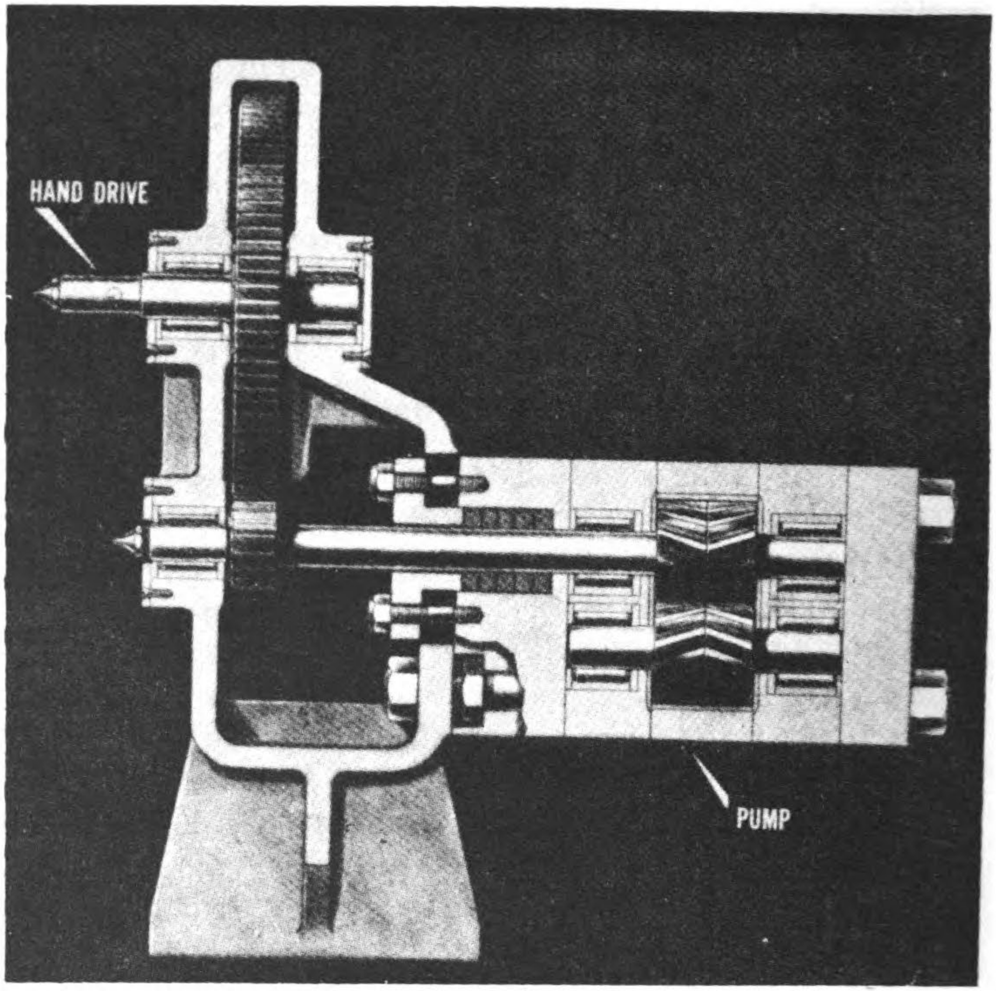


Figure 6–7.—Hand-driven fuel oil service pump.

charge side back to the suction side. Rotary pumps are designed to operate at relatively low speeds in order to maintain these clearances; operation at higher speeds would cause erosion and excessive wear, which would result in increased clearances.

Types of Rotary Pumps

Classification of rotary pumps is generally made according to the type of rotating element. In the following paragraps we will discuss briefly the main features of gear pumps and screw pumps.

The SIMPLE GEAR PUMP has two spur gears which mesh together and revolve in opposite directions. One is the

DRIVING GEAR, and the other is the DRIVEN GEAR. Clearances between the gear teeth and the casing and between the gear faces and the casing are only a few thousandths of an inch. The action of the unmeshing gears draws the liquid into the suction side of the pump. The liquid is then trapped in the pockets formed by the gear teeth and the casing, so that it must follow along with the teeth. On the discharge side, the liquid is forced out by the meshing of the gears.

The HERRINGBONE GEAR PUMP is a modification of the simple gear pump. In the herringbone gear type, one discharge phase begins before the previous discharge phase is entirely complete; and this overlapping tends to give a steadier discharge pressure than is found in the simple gear pump. The hand-driven fuel oil service pump shown in figure 6–7 is a herringbone gear pump. Power-driven pumps of this type are sometimes used for low-pressure fuel oil service, lubricating oil service, and Diesel oil service.

The HELICAL GEAR PUMP is still another modification of the simple gear pump. Because of the helical gear design, the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump; and the discharge flow is, accordingly, even smoother. Since the discharge flow is smooth in the helical gear pump, the gears can be designed with a small number of teeth—thus allowing increased capacity without sacrificing smoothness of flow.

The pumping gears in this type of pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. (As a matter of fact, metallic contact between the teeth of the pumping gears would provide a tighter seal against slippage; but it would cause rapid wear of the teeth because foreign matter in the pumped liquid would be present on the contact surfaces.)

Roller bearings at both ends of the gear shafts maintain proper alinement, and so minimize the friction loss in the transmission of power. Stuffing boxes are used to prevent

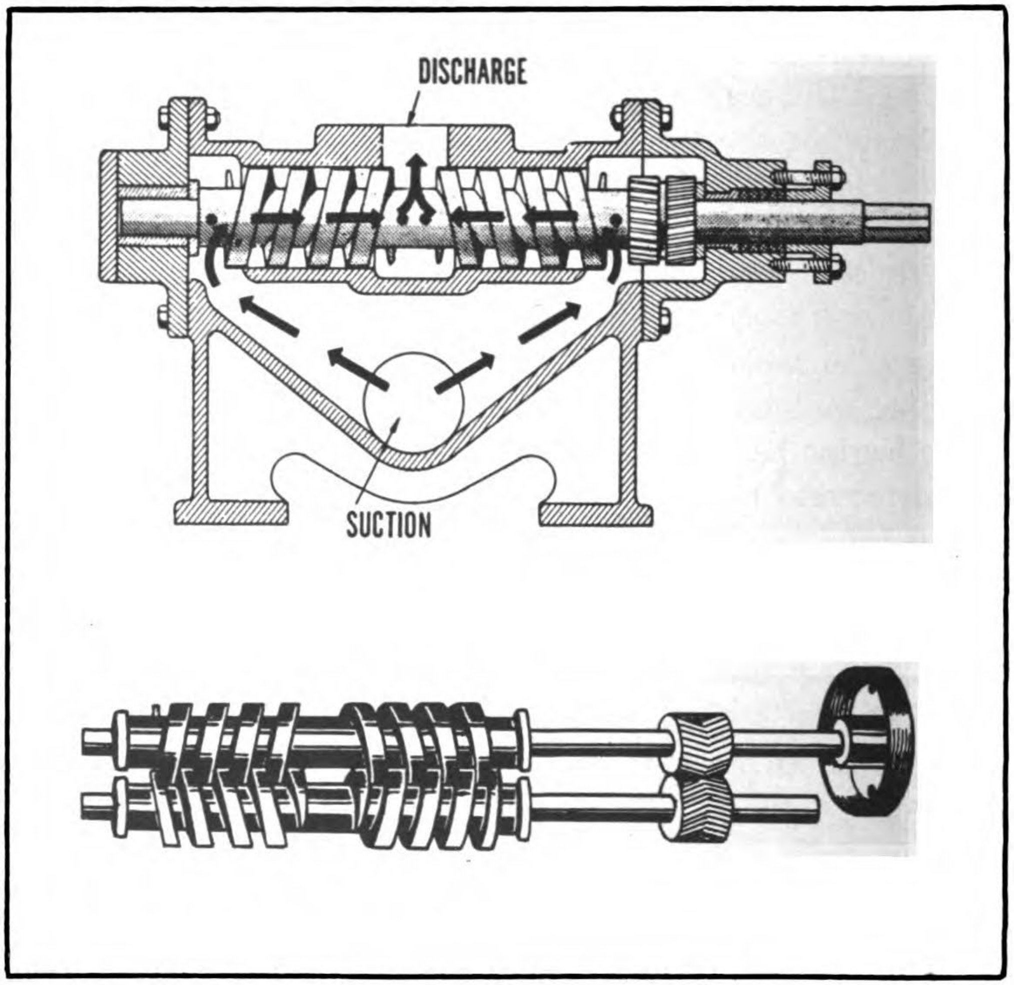


Figure 6–8.—Double-screw low-pitch pump.

leakage at the shafts. The helical gear pump is used to pump nonviscous liquids and light oils at high speed. It can also be used to pump heavy, viscous materials at lower speed.

The LOBE-TYPE PUMP is still another variation of the simple gear pump. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. The rotors are driven by external spur gears on the rotor shafts. Some lobe pumps are made with replaceable inserts (gibs) at the extremities of the lobes. These inserts take up the wear which would otherwise be sustained by the ends of the lobes; and, in addition, they maintain a tight seal between the lobe ends and the casing. The inserts are usually seated on a spring, and are thus able to automatically com-

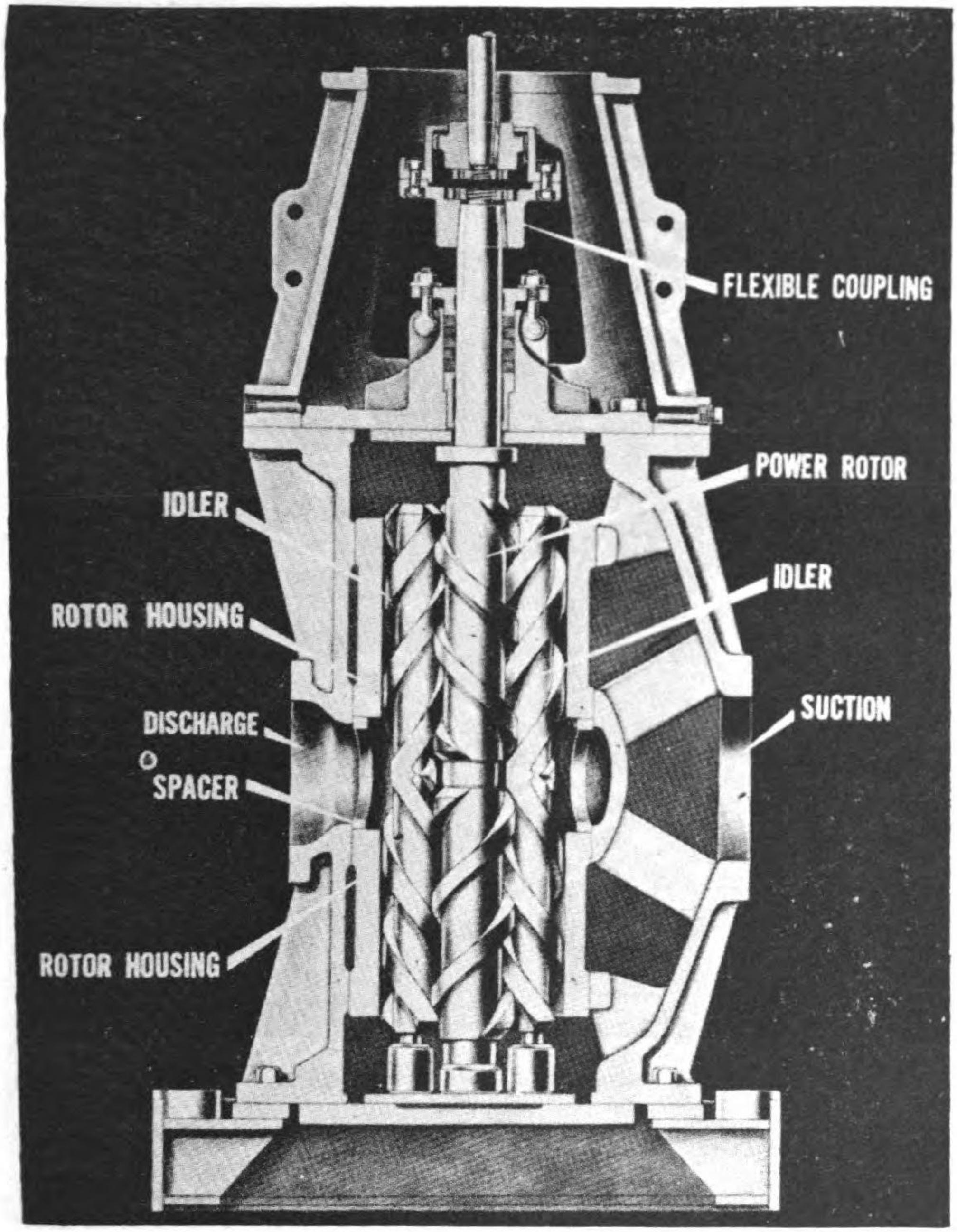


Figure 6–9.—Cutaway view of triple-screw high-pitch pump.

pensate for considerable wear of both the gibs and the casing. Replaceable cover plates (liner plates) are fitted at each end of the casing, where the lobe faces cause heavy wear.

There are several types of SCREW PUMPS. The main points of difference between the various types are the number of intermeshing screws and the pitch of the screws. A DOUBLE-

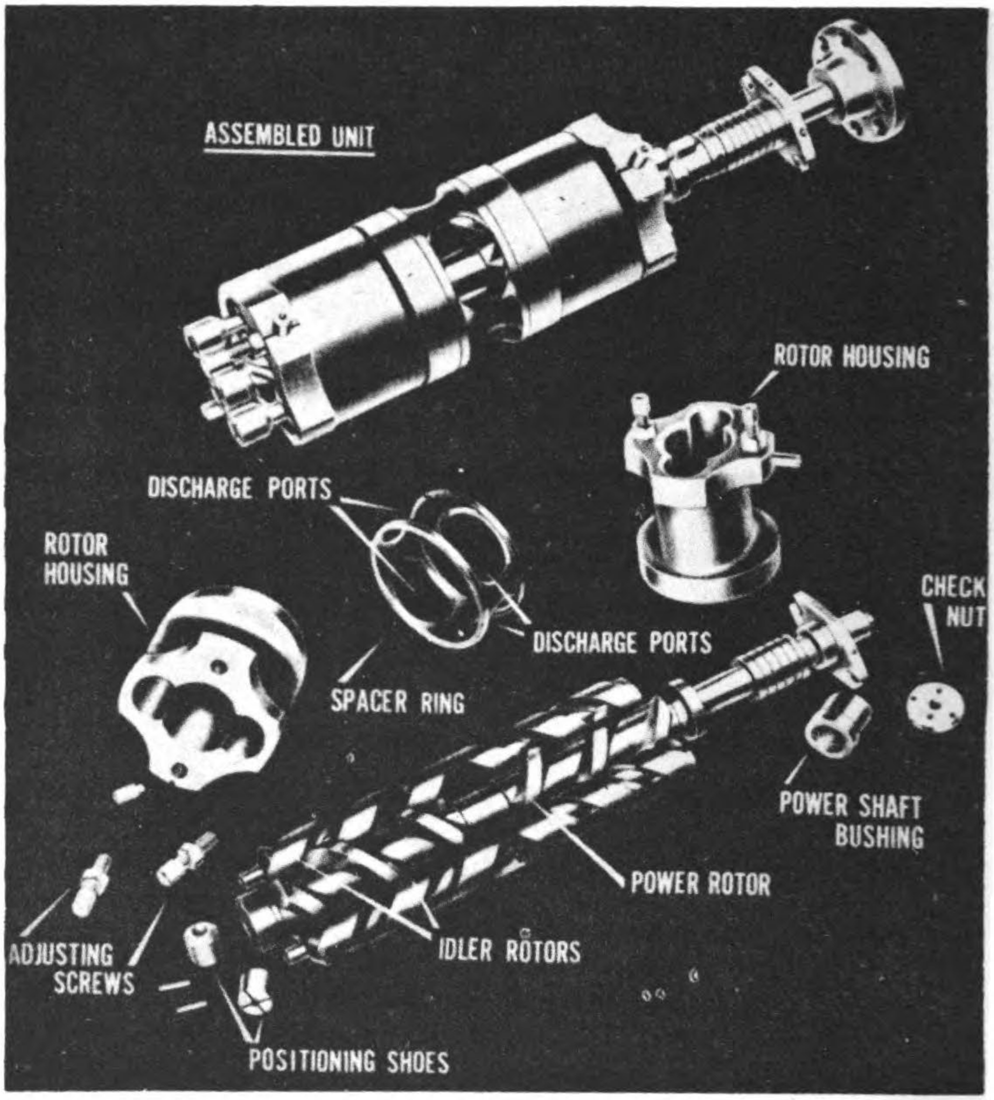


Figure 6–10.—Dismantled triple-screw high-pitch pump.

SCREW LOW-PITCH PUMP is shown in figure 6–8. This type of pump is widely used on board ship as a fuel oil service pump. Figures 6–9 and 6–10 show a TRIPLE-SCREW HIGH-PITCH PUMP.

Operation of Rotary Pumps

The general procedure for starting and operating a rotary pump is as follows:

1. Check the lubricating oil level and add oil if necessary. Rotate the handle of the lube oil filter when starting the pump, and at least once during each watch. If the rotary pump is lubricated by a separate lubricating

pump, be sure to open and adjust all oil delivery and return valves.

2. Lubricate the linkage and slides on the speed-limiting governor. If a gravity-feed oil cup is provided for the end bearing of the governor spindle, lift the snap tip needle valve to a vertical position, and check to be sure that oil is being fed at the proper rate—about 5 to 10 drops per minute, or as recommended by the manufacturer's instruction book.
3. Open all turbine drains.
4. Open the valves on the pump packing gland seals (where such valves are fitted).
5. Open the steam and exhaust root valves.
6. Open the exhaust valve at the pump.
7. Lift all sentinel and relief valves by hand.
8. Open pump suction and discharge valves, and open line valves if necessary.
9. Crack open the steam throttle valve at the pump to free the lines and casing of water. Close the drains when the turbine is free of condensate. Admit sufficient steam through the throttle valve to turn the unit over at the minimum speed required to develop and maintain lube oil circulation. Continue to operate at that speed until the turbine is thoroughly warmed and it is definitely established that everything is working satisfactorily.
10. Open the throttle gradually and bring the unit up to the desired speed

    OR

    for motor-driven pumps, push the START button after the pump is lined up and ready to operate.
11. Check the lube system to see that the bearings are getting an adequate supply of oil. Check all gages and thermometers to see that proper pressures and temperatures are being developed.
12. When the lube oil temperature reaches 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit operating conditions.

Be sure that all air is vented from the water side of the cooler.

13. On turbine-driven units, make sure that the speed-limiting governor is free and operable. If an over-speed trip is installed, set it and trip it by hand.
14. Adjust pump shaft packing glands and gland sealing needle valves, if overheating or excessive leak-off indicates the need for adjustment.
15. Shift the pump over to governor control, and open the throttle wide to ensure a sufficient quantity of steam for the pump at all loads.
16. Follow all applicable operating instructions given in the chapter on auxiliary turbines.

It is particularly important to keep a close watch on both pump and turbine during the first few minutes of operation. Pressures, temperatures, and speeds must be checked, so that any dangerous conditions can be spotted and corrected, before damage occurs. The unit should be closely watched until temperatures have reached normal operating values and have leveled off.

The procedure for stopping and securing a rotary pump is as follows:

1. Close the throttle (OR stop the motor).
2. Close the pump discharge and suction valves, and line valves if necessary.
3. Close the exhaust valve at the pump.
4. Open the turbine casing drains.
5. Secure the cooling water to the oil cooler. If a separate lube oil pump is installed, close all oil supply and return valves.
6. Close the steam and exhaust root valves.
7. Close the turbine drains, after the casings and lines are drained.
8. Secure the pump governor actuating line, and open the governor bypass valve.
9. After the pump is secured, check the turbine exhaust pressure gage and the pump suction pressure and vacuum gage. Unusual readings on the turbine exhaust pressure gage indicate that the steam is leaking through

the steam supply valve or the exhaust valve, causing pressure to build up inside the turbine casing. Unusual readings on the pressure and vacuum gage at the suction side indicate that oil pressure is being built up inside the pump casing because the discharge valve is leaking.

If the pump fails to build up the required pressure, or if it fails to discharge fluid when the discharge valve is open and the pump is up to speed, stop the unit. Check over the pump completely to see that the proper valves are open in the pump and piping system. The trouble may be a faulty relief valve, a broken valve spring, or a valve disk which has been damaged or hung up. You should also check for loose packing glands on the pump shaft, loose packing glands on the stems of suction valves, loose strainer covers, and other possible sources of air leakage. See that there are no clogged suction strainers or suction lines which might be causing the trouble. If a motor-driven pump fails to develop pressure when it is first operated after major repairs have been made to the electrical end, check to be sure that the pump is rotating in the proper direction.

Lube Oil Pumps on Auxiliary Machinery

Small lubricating oil pumps are installed on many pumps, forced draft blowers, and other kinds of fireroom auxiliary

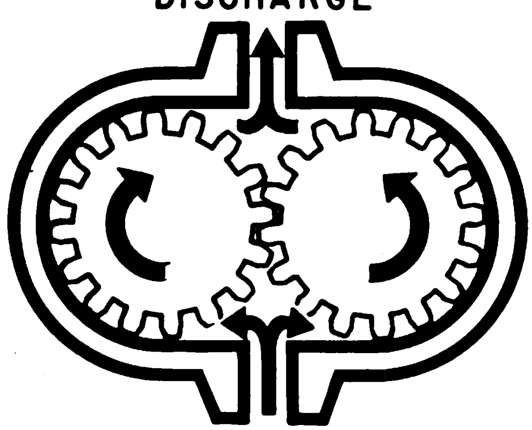


Figure 6–11.—Action of simple gear pump.

machinery. These lubricating oil pumps are usually positive displacement rotary pumps of the simple gear type. Figure 6–11 illustrates the operating principles of this type of pump.

A certain amount of maintenance and repair is required to keep these small lube oil pumps in proper condition. You may have to renew the gears, the casing itself, or the gaskets which are sometimes fitted between the casing flanges. It is essential that designed clearances be maintained. Do not attempt to repair this or any other type of pump without first assembling all pertinent drawings, dimension data, and pump history. Do not attempt to fit a gasket to a lube oil pump which is not designed to have one. If a gasket is to be renewed, be sure that you use one of proper thickness.

Tests and Inspections

The following tests and inspections should be made on rotary pumps, and the results should be entered in the appropriate check-off list or log:

DAILY: Turn idle pumps by hand.

WEEKLY: Run the pump under power. Lift all relief valves by hand. Check the operation of the discharge check valves (if installed). Check the condition of the lubricating oil; in particular, check for the presence of water in the lube oil.

QUARTERLY: Test all relief valves by steam, water, or oil, as appropriate. Measure thrust bearing clearances, and check the position of pump rotors. Check all foundation bolts and dowel pins. Slowly close the suction valve at the pump and note the amount of vacuum pulled; if the pump fails to produce the required vacuum, it should be opened and repaired as necessary. Check the lubricating system and renew oil and grease.

ANNUALLY: Open the pump, turbine, and reduction gear casings for inspection and cleaning. Measure clearances of all internal wearing parts, and renew parts if necessary.

Perform all daily, weekly, quarterly, biannual, and annual tests and inspections required on the turbine end, as described in chapter 5.

Safety Precautions

The following precautions must be observed in the operation of rotary pumps:

1. See that all relief valves are tested at the appropriate intervals. Be sure that relief valves function at the designated pressures.
2. Never attempt to jack over a pump by hand while the steam or power is on.
3. Do not tie down the overspeed trip, the speed-limiting governor, or the speed-regulating governor. Do not in any way render these devices inoperable.
4. Never operate a positive displacement rotary pump with the discharge valve closed, unless provision is made for adequate discharge.
5. Observe all appropriate safety precautions given in the chapter on auxiliary turbines.

CENTRIFUGAL PUMPS

The basic principles of operation of the centrifugal pump are discussed in *Fireman*, NavPers 10520–A. As you will recall, the centrifugal pump utilizes the throwing force of a rapidly revolving IMPELLER. The liquid is pulled in at the center or EYE of the impeller and is discharged at the outer rim of the impeller.

By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity. The liquid is then slowed down by being led through a volute or through a series of diffusing passages. As the velocity of the liquid decreases, its pressure increases; and thus its kinetic energy is transformed into potential energy.

Types of Centrifugal Pumps

There are many different types of centrifugal pumps, but the two which you are most likely to encounter on board ship are the volute pump and the volute turbine pump.

The VOLUTE PUMP is shown in figure 6–12. In this pump,

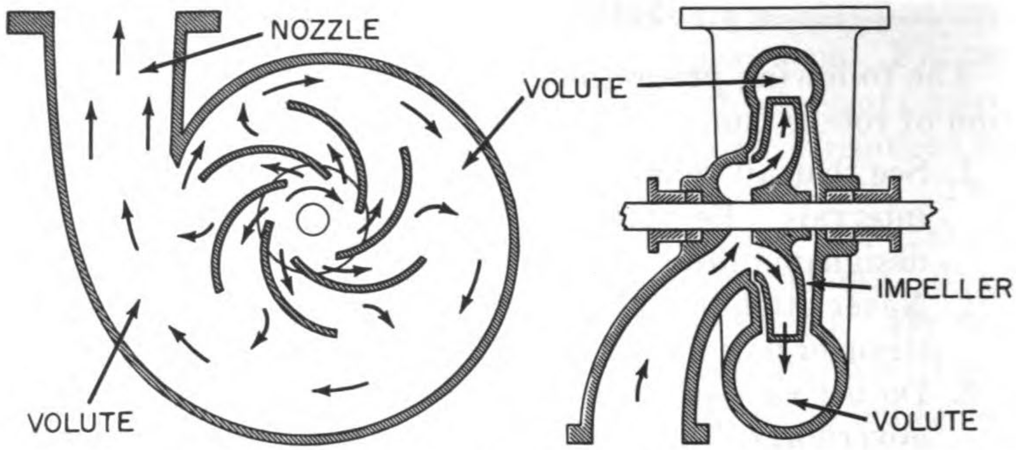


Figure 6–12.—Simple volute pump.

the impeller discharges into a volute—that is, a gradually widening channel in the pump casing. As the liquid passes through the volute and into the discharge nozzle, a great part of its kinetic energy is converted into potential energy.

In the VOLUTE TURBINE PUMP, shown in figure 6–13, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes which surround the impeller. The liquid is forced through gradually widening passages in the diffuser

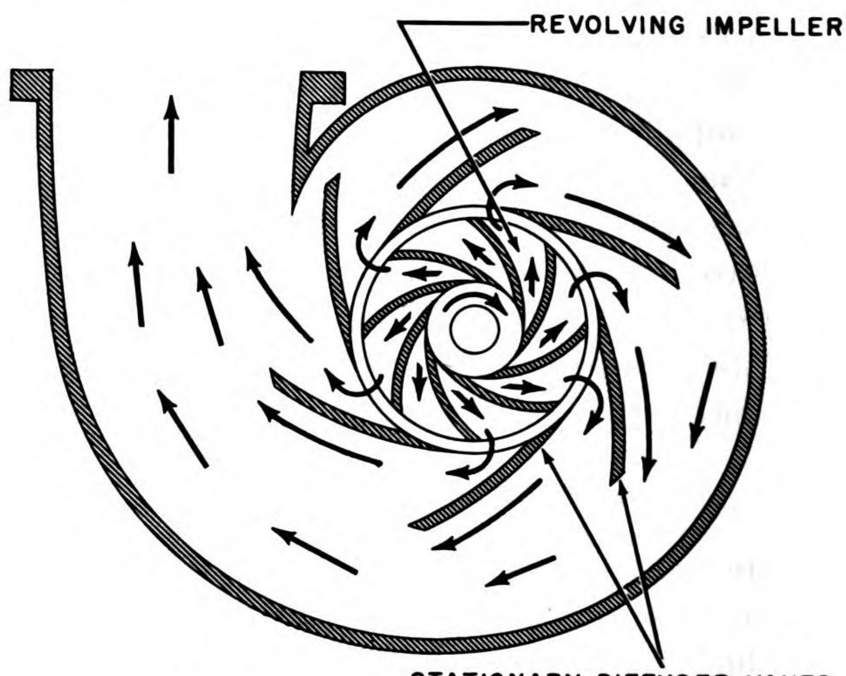


Figure 6–13.—Volute turbine pump.

ring (not shown) and into the volute. Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is in this type of pump an almost complete conversion of kinetic energy to potential energy.

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE-STAGE or MULTISTAGE. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing; as a rule, each impeller acts separately, discharging to the suction of the next-stage impeller. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as SINGLE-SUCTION or DOUBLE-SUCTION. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions. Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls which extend from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps used in the Navy have closed impellers.

Construction of Centrifugal Pumps

As a rule, the casing for the liquid end of a pump with a single-suction impeller is made with an end plate which can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one half of the casing may be lifted without disturbing the pump.

Since the impellers rotate at very high speed, they must be carefully machined in order to minimize friction; and they must be balanced in order to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates, in order to minimize leakage from the discharge side of the pump casing to the suction side.

Because of the high rotational speed of the impeller and the necessarily close clearance, the running surfaces of both

the impeller hub and the casing at that point are subject to relatively rapid wear. To eliminate the need for renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring is attached to each outer hub of the impeller, and rotates with the impeller; a matching ring is attached to the casing, and is therefore stationary. The replaceable ring on the outer hub of the impeller is called the IMPELLER WEARING RING, and the ring attached to the casing is called the CASING WEARING RING. (Wearing rings are shown on the main feed pump illustrated in figure 6–14.)

It should be noted that some small pumps with single-suction impellers are made with a casing wearing ring only, and no impeller ring; in this type of pump, the casing wearing ring is fitted into the end plate.

In many centrifugal pumps, the shaft is fitted with replaceable sleeves. The advantage of using sleeves is that they can be replaced more economically than the entire shaft.

Recirculating lines are installed on centrifugal pumps in order to prevent the pumps from overheating and becoming vapor-bound when the discharge is entirely shut off. Seal piping is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box. Seal piping leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is perforated so that water can flow in either direction along the shaft, between the shaft and the packing.

Bearings support the weight of the impeller and maintain the position of the impeller, both radially and axially. Most centrifugal pumps have a built-in bearing lubrication system, complete with lube oil pump, sump, cooler, strainer, and temperature and flow indicators.

The power end of a centrifugal pump may be either a steam turbine or an electric motor. For most constant-speed applications, the turbine drive has no particular advantage

over the motor drive. On naval vessels, however, where reliability and flexibility are essential considerations, most large centrifugal pumps are turbine driven. Smaller pumps, such as those used for in-port or cruising operation, are often motor driven.

The turbines used for centrifugal pumps are usually single-stage impulse turbines. As a rule, high-pressure centrifugal pumps are direct-drive—that is, the impeller rotates at the same rpm as the turbine. However, some low-pressure centrifugal pumps have reduction gears installed between the turbine and the impeller; this allows the turbine to operate at a high speed and the impeller to operate at a lower speed, thus obtaining maximum efficiency from both turbine and pump.

Fireroom Applications

Centrifugal pumps are widely used on board ship for pumping nonviscous liquids. In the fireroom, you may find several important centrifugal pumps: the main feed pump, the feed booster pump, the feed heater drain booster pump, the fire and flushing pump, condensate pumps and auxiliary circulating pumps.

A typical MAIN FEED PUMP is shown in figure 6–14. Main feed pumps are of the high-speed, horizontal, turbine-driven type. Main feed pumps usually operate at a discharge pressure of 75 to 150 psi gage above the maximum steam drum pressure; if automatic feed water regulators are installed, the discharge pressure of the main feed pump must be even higher. It is necessary for a main feed pump to operate at varying speeds, in order to maintain a constant discharge pressure under all conditions of load. A pump pressure-regulating governor automatically regulates the admission of steam to the turbine so as to control the discharge pressure.

FEED BOOSTER PUMPS are used in closed feed systems only. The booster pump takes suction from the deaerating tank and discharges into the main feed pump suction. The booster pump provides a suction pressure of about 35 to 55 psi for the main feed pump, and thus enables the main feed pump to

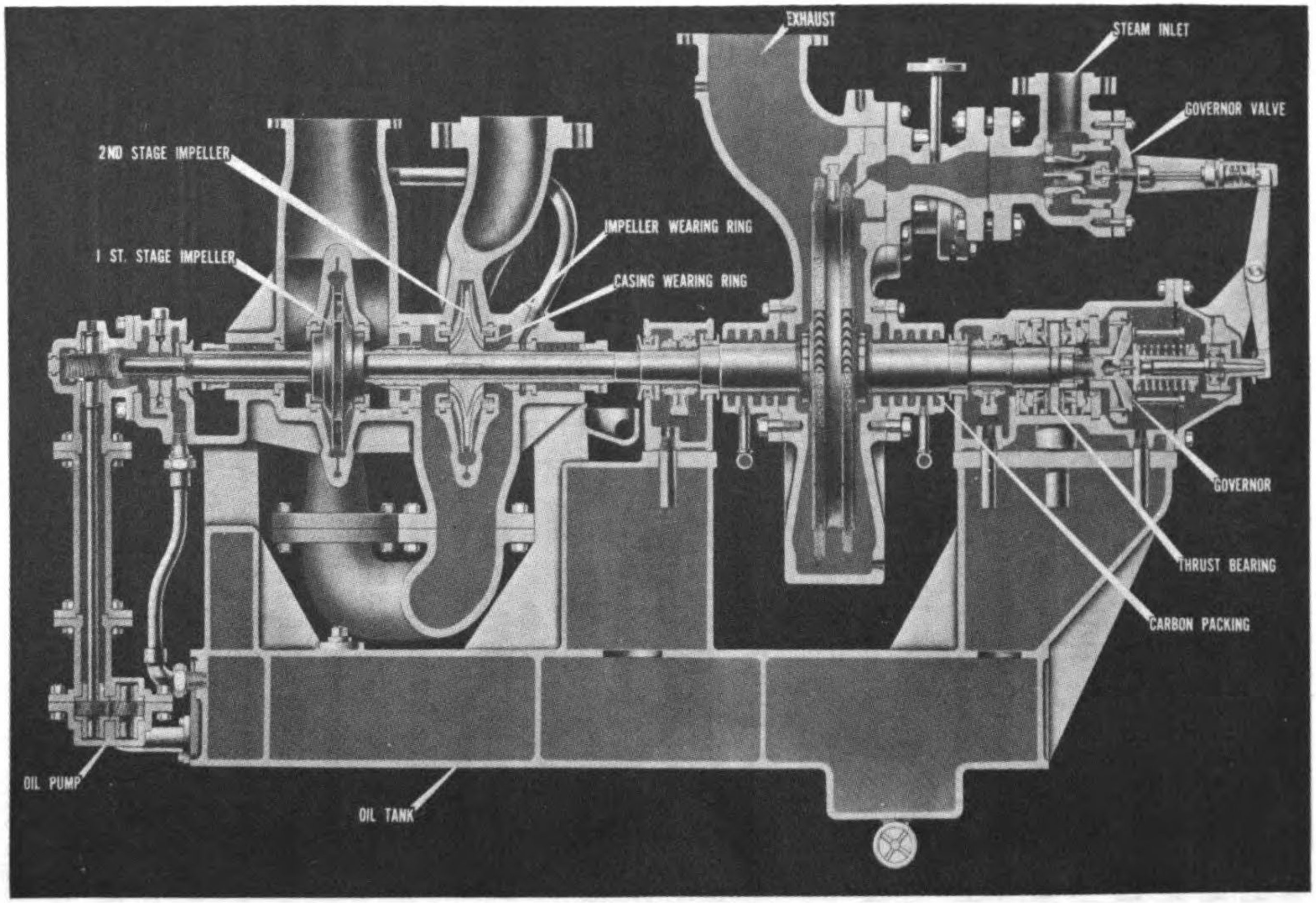


Figure 6–14.—Main feed pump.

handle feed water at high temperatures, without becoming vapor-bound and losing suction. Feed booster pumps operate at or near constant speed. In the case of turbine-driven pumps, the speed is maintained approximately constant by the turbine speed-limiting or speed-regulating governor.

FEED HEATER DRAIN BOOSTER PUMPS are usually single-stage centrifugal pumps. Feed heater drain booster pumps are needed to force the water from the feed heater drain into the feed suction main, where it is picked up by the main feed pump.

The FIRE AND FLUSHING PUMP is a single-stage, double-suction, volute-type centrifugal pump. As a rule, this pump is driven either by an electric motor or by a turbine. In some installations, however, one end of the pump shaft is connected to a motor and the other end is connected to a steam turbine. In all cases, a flexible coupling is used. Sometimes a type of coupling is used which allows the turbine to remain idle while the motor is driving the pump.

Operation of Centrifugal Pumps

The operating instructions for centrifugal pumps vary somewhat from one type to another. Before attempting to operate any pump, therefore, you should read the posted operating instructions, read the valve labels, and check the piping markings.

The posted instructions for starting and operating a centrifugal pump will probably read something like this:

1. Check the lube oil level in the sump tank or bearing housing. Fill oil cups or reservoirs, if fitted. Rotate the handle of the lube oil filter before starting the pump, and at least once during each watch.
2. Lubricate the linkage and slides on the speed-limiting governor. If a gravity-feed oil cup is provided for the end bearing of the governor spindle, lift the snap tip of the needle valve to a vertical position; and check to be sure that oil is being fed at the proper rate—about 5 to 10 drops per minute, or as recommended by the manufacturer's instruction book.

3. Open the pump suction valve.
4. Check the suction pressure.
5. Make sure that the recirculating valve (if installed) is locked in the OPEN position.
6. Open vents on the pump end.
7. Open all drains on the steam end.
8. Open the turbine exhaust valve.
9. Open the bypass around the constant-pressure pump governor.
10. Crack open the turbine throttle (OR start the motor).
11. Close the drains when steam blows through them.
12. Increase the throttle opening and run the pump fast enough so that the lube oil will begin to circulate.
13. Make sure that the speed-limiting governor is free and operable. If an overspeed trip is installed, set it and trip it by hand.
14. When the vents on the pump end discharge solid streams of water, close them.
15. Continue to run the pump at moderate speed until the oil temperature reaches 100° F. Be sure to keep the pump running fast enough to maintain an adequate discharge pressure; if the discharge is too low, the pump packing will not be lubricated properly.
16. When the lube oil temperature reaches 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit operating conditions. Be sure that all air is vented from the water side of the cooler.
17. When ordered to cut in the pump, close the constant-pressure governor bypass valve and open the throttle valve all the way. Bring up the discharge pressure to the required line pressure by putting tension on the constant-pressure governor spring, and slowly open the discharge valve.
18. Follow all applicable operating instructions given in the chapter on auxiliary turbines.

If the pump fails to build up pressure, notify the PO in charge of the fireroom watch. If the pressure goes too high,

secure the pump and cut in another one; or, if the pump must be operated, use manual control.

Instructions for stopping and securing a centrifugal pump will, in general, read something like this:

1. Release tension on the constant-pressure governor spring.
2. Close the throttle valve (OR stop the motor).
3. Close the exhaust valve.
4. Close the suction valve.
5. Close the pump discharge valve.
6. Open the turbine drains.
7. Close the drains, after the turbine is completely drained.
8. Secure the cooling water to the lube oil cooler.

Care and Maintenance of Centrifugal Pumps

Some of the information which you must have in order to give proper care and maintenance to centrifugal pumps is given in this section. For further details, and for specific information on any one pump, you should consult BuShips *Manual* and the appropriate manufacturer's instruction books. Before attempting to repair a pump, you should assemble the pump history and all pertinent drawings and dimensional data.

LUBRICATION is essential for the proper operation of centrifugal pumps, and inadequate lubrication is a primary cause of pump failure. The supply of oil to the bearings must be checked frequently during each watch. Grease cups and bearing housings must be kept filled with lubricant, and free of water or other foreign matter. Lubricating oil should be changed whenever it foams excessively, becomes emulsified, or contains dirt or sludge.

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When you are operating a centrifugal pump, be sure that there is always a slight trickle of water coming out of the stuffing box or seal.

Stuffing box packing should be renewed about once every 2 months. You should install the packing so as to give a uniform thickness all around the shaft sleeves. When installing new packing, pack the stuffing box loosely and set up lightly on the packing gland; then, when the pump is in operation, tighten the gland in steps so as to compress the packing gradually. This procedure will prevent excessive heating and possible scoring of the shaft or shaft sleeves.

Some stuffing boxes are fitted with packing beyond the lantern ring; and this packing must be replaced when the stuffing box is being repacked. It is important, also, to make sure that the sealing water connection to the lantern ring is not blocked off by the packing.

Unusually rapid wear of the packing may be caused by roughness of the shaft. A rough shaft should be sent to the machine shop for a finishing cut to smooth the surface.

Water flingers are fitted on shafts outboard of stuffing box glands, to prevent water from following along the shaft and entering the bearing housings. The flingers must be tightly fitted. If the flingers are fitted on the shaft sleeves, rather than on the shaft, make sure that no water is allowed to leak under the sleeves. If leakage does occur, a fiber washer should be fitted between the end of the sleeves and the shaft shoulder, and all clearances between shaft and sleeve should be filled with white or red lead.

The clearances between impeller wearing rings and casing wearing rings must be maintained within the specified tolerances. Clearances are shown on the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. This job can be done by ship's force, but it requires the complete disassembly of the pump. If it is necessary for you to undertake this job, be sure to follow the manufacturer's instruction book carefully. Improper fitting of the rings or incorrect reassembly of the pump can result in serious damage.

Shaft alinement must be checked frequently. If shafts are out of line, the unit must be realined in order to prevent

shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Shaft alinement should be checked with all piping in place and all tanks and piping filled; and due allowance must be made for the change in position of parts from cold-check conditions to hot-operating conditions.

Tests and Inspections

The following tests and inspections should be made on centrifugal pumps, and the results should be entered in the appropriate check-off list or log:

DAILY: Turn idle pumps by hand.

WEEKLY: Run the pump under power. Lift all relief valves by hand. Check the operation of the discharge check valves. Determine the condition of the lubricating oil.

QUARTERLY: Test all relief valves by steam, water, or oil, as appropriate. Measure the thrust bearing clearance. Check the axial position of the pump impellers. Check bearing clearances by leads or bridge gage readings. Examine and set up on all foundation bolts; secure all foundations dowel pins. Check all water-lubricated bearings and shafts for wear and scoring. Clean the lubricating system and renew oil or grease.

ANNUALLY: Open the pump, turbine, and reduction gear casings for inspection and cleaning. Check clearances of casing throat bushings and of impeller and casing wearing rings; renew if necessary. Examine all impellers, diffusers, turbine rotors, turbine blading, carbon packing, shafts, and shaft sleeves.

Perform all daily, weekly, quarterly, biannual, and annual tests and inspections required on the turbine end, as described in chapter 5.

Safety Precautions

The following safety precautions must be observed in connection with the operation of centrifugal pumps:

1. See that all relief valves are tested at the appropriate intervals. Be sure that relief valves function at the designated pressures.

2. Never attempt to jack over a pump by hand while the steam valve to the pump is open or while the power is on.
3. Do not tie down the overspeed trip, the speed-limiting governor, or the speed-regulating governor. Do not in any way attempt to render these devices inoperable. Be sure that speed-limiting and speed-regulating governors are properly set.
4. Do not use any boiler feed system pump for any service other than boiler or feed water service, except in emergency.
5. Observe all appropriate safety precautions given in the chapter on auxiliary turbines.

Pump Regulating Devices

Many pumps are fitted with devices for regulating either speed or discharge pressure, or both. As a rule, regulators or governors are not used on reciprocating pumps; but practically all rotary and centrifugal pumps have some type of governor.

The constant-pressure pump governor commonly used for regulating pump discharge pressure is essentially a spring-controlled reducing valve governor which controls the admission of steam to the turbine. This is described in detail in the chapter on valves, pipe fittings, and piping.

Devices for controlling the speed of a turbine-driven pump operate by controlling the admission of steam to the turbine. The amount of steam admitted determines the speed of the turbine, and this in turn controls the speed of the pump. Speed-controlling devices are described in the chapter on auxiliary turbines.

QUIZ

1. How would you classify a reciprocating pump in which the pump rod is a direct extension of the steam piston rod?
2. How would you classify a reciprocating pump in which each stroke serves both to draw in and to discharge liquid?
3. What is the relative size of the steam piston and the pump plunger, in a high-pressure reciprocating pump?
4. What purpose is served by the valve gear on a reciprocating pump?
5. What devices are used on some reciprocating pumps to allow a gradual, rather than sudden, drop in discharge pressure at the end of each stroke?
6. Why is the emergency or auxiliary feed pump NOT fitted with an air chamber or a snifter valve?
7. By what means could a short stroke on a reciprocating pump cause the pump to stop operating?
8. How can the stroke be lengthened on a reciprocating pump?
9. What is the first step to take in repairing any type of pump?
10. What controls the amount of flow in an axial-piston variable stroke pump?
11. In a radial-piston variable stroke pump, what position of the floating ring is necessary before pumping can occur?
12. What is meant by a POSITIVE-DISPLACEMENT pump?
13. Which simple gear pump will have the greater capacity—one with a relatively small number of teeth, or one with a larger number of teeth?
14. In a lobe-type pump, what two purposes are served by having replaceable inserts at the extremities of the lobes?
15. What two types of centrifugal pumps are commonly used on board ship?
16. In a centrifugal pump, where is the kinetic energy of the liquid converted into potential energy?
17. How often should centrifugal pump stuffing box packing be renewed?

CHAPTER · 7

FORCED DRAFT BLOWERS

In modern, oil-burning vessels, forced draft blowers are used to furnish the large amount of air which is required for combustion of the fuel. A forced draft blower is essentially a very large fan, fastened to a shaft and housed in a metal casing. Forced draft blowers may be installed either vertically or horizontally. As a rule, two blowers are furnished for each boiler, and are synchronized for equal distribution of load.

In most installations, the forced draft blowers are driven by steam turbines. However, some small blowers for in-port use and many blowers used on auxiliary vessels are driven by electric motors. Turbine-driven blowers are direct-drive, as a rule, but some geared-turbine drives are used.

TYPES OF BLOWER INSTALLATIONS

In the CLOSED FIREROOM type of installation, the entire fireroom is under air pressure created by the forced draft blowers. In order to maintain pressure in a closed fireroom, it is necessary to keep the whole space airtight. Air-lock doors are used for access, and all fittings through bulkheads and decks are tightly packed. Although the closed fireroom type of installation was once used extensively, it is now found only on those few ships which still have low-pressure boilers.

In the OPEN FIREROOM, found on practically all modern naval vessels, the forced draft blowers take suction from

the space between the inner and outer stack casings, and discharge slightly preheated air into a duct which leads to the space between the inner and outer boiler casings. The open fireroom is under atmospheric pressure only.

AUTOMATIC SHUTTERS

Balanced, automatic shutters are installed in the discharge ducts between each propeller-type blower and the boiler casing. These shutters MUST operate freely. If the shutters to an idle blower fail to close, the blower may be rotated in reverse; this will damage the blower, since the lubricating system works only when the blower is rotating in the proper direction.

Centrifugal blowers are fitted with flaps in the suction duct; in the event of casualty to one blower, air will blow back through it and close the flaps, thus preventing loss of air pressure.

The use of automatic shutters (for propeller-type blowers) and flaps (for centrifugal blowers) makes it possible to secure any blower which, because of low steaming rate, is not required for satisfactory operation of the plant. The shutters or flaps may be locked in the closed position when a blower is for any reason taken out of service.

TYPES OF FORCED DRAFT BLOWERS

Two main types of forced draft blowers are used in naval vessels: centrifugal-type blowers and propeller-type blowers. The essential difference between the two types is in the direction of air flow. The centrifugal-type blower sucks air in at the center of the fan and discharges it at the outer edge of the blades. The propeller-type blower moves the air axially—that is, it propels the air straight ahead, in a direction parallel to the axis of the shaft.

Although centrifugal-type blowers may still be found on some older ships, propeller-type blowers are now being installed on most new construction. Propeller-type blowers have the following advantages over centrifugal-type blowers:

1. The propeller-type blower slows down when either the intake damper or the discharge damper is closed, since these conditions cause an increased load on the blower. The centrifugal-type blower, on the other hand, loses its load under these conditions and tends to overspeed or "run away."
2. Propeller-type blowers do not oppose each other as much as centrifugal-type blowers do, when running at different speeds and discharging into the same space. Centrifugal-type blowers must be brought to as nearly equal speeds as possible, when discharging into the

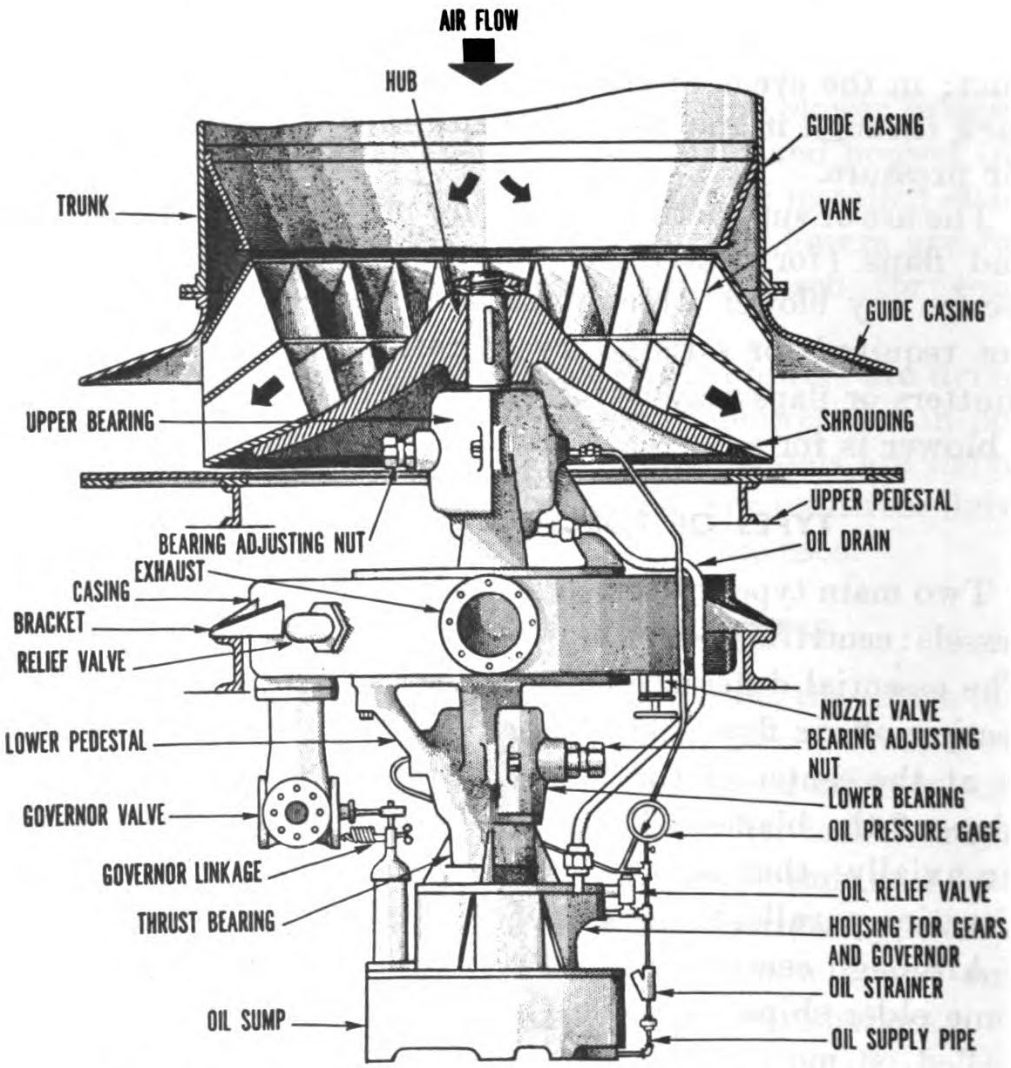


Figure 7–1.—Vertical centrifugal-type forced draft blower.

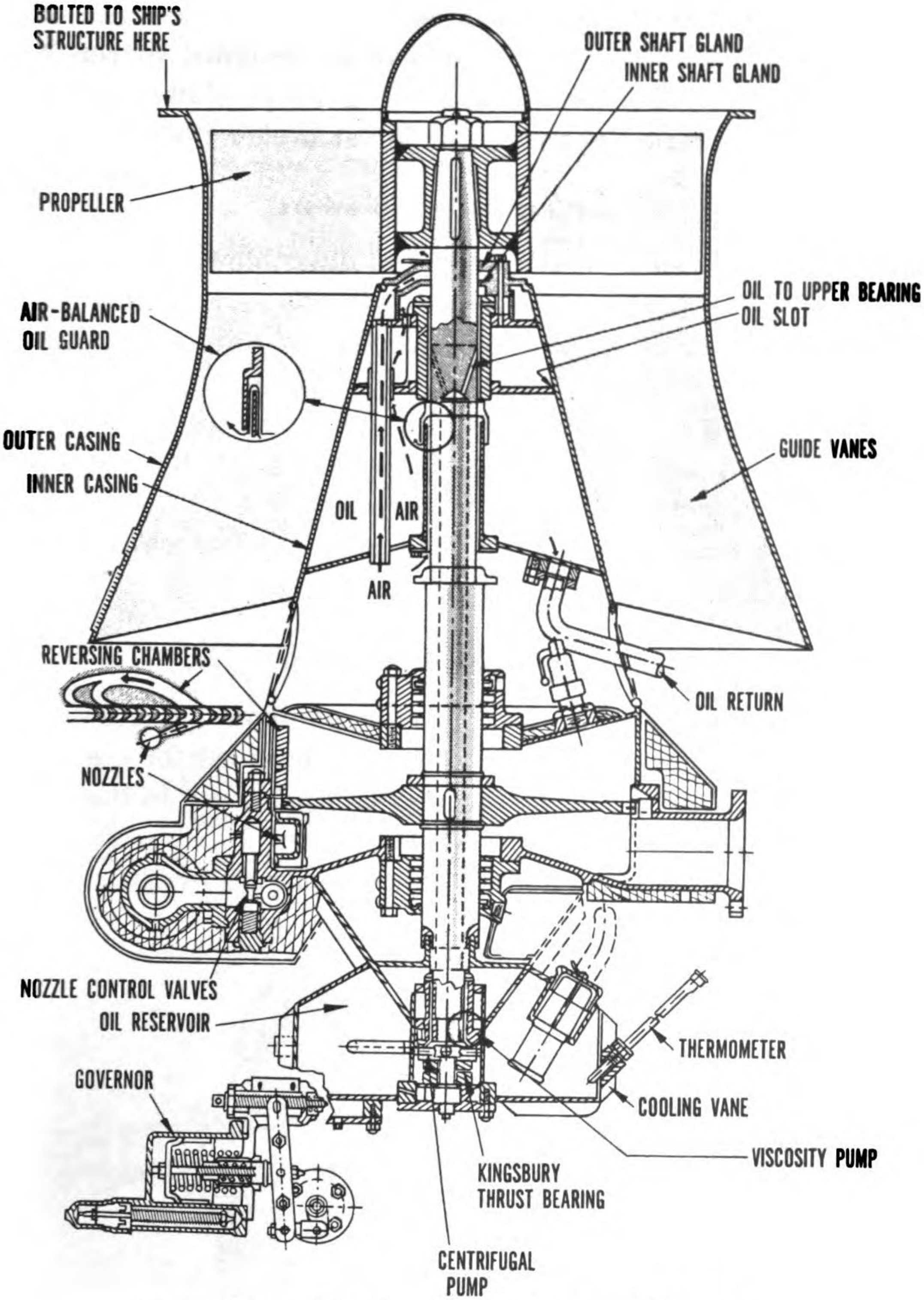


Figure 7–2.—Vertical propeller-type forced draft blower.

same space; if two centrifugal-type blowers are running at different speeds, one blower will tend to force air backwards through the other.

3. The propeller-type blower can be designed to run at higher speeds than the centrifugal-type blower and to deliver larger quantities of air at higher pressure.

Centrifugal-Type Blowers

A vertical centrifugal-type forced draft blower for closed fireroom use is shown in figure 7–1. The single-inlet fan consists of vanes and shrouding, mounted on a heavy hub. The fan rotates inside a guide casing. Inlet trunks and diffusers are fitted to and around the fan, to direct the air into the fan and to guide the air as it discharges into the fireroom. The entire rotating element is supported and guided by the two main bearings and a thrust bearing which is located just below the lower main bearing.

Propeller-Type Blowers

A vertical propeller-type forced draft blower is shown in figure 7–2. Although this blower was designed for use in a closed fireroom, it is similar, in general principle, to the propeller-type blowers used in open firerooms.

The entire weight of the blower is carried by the upper

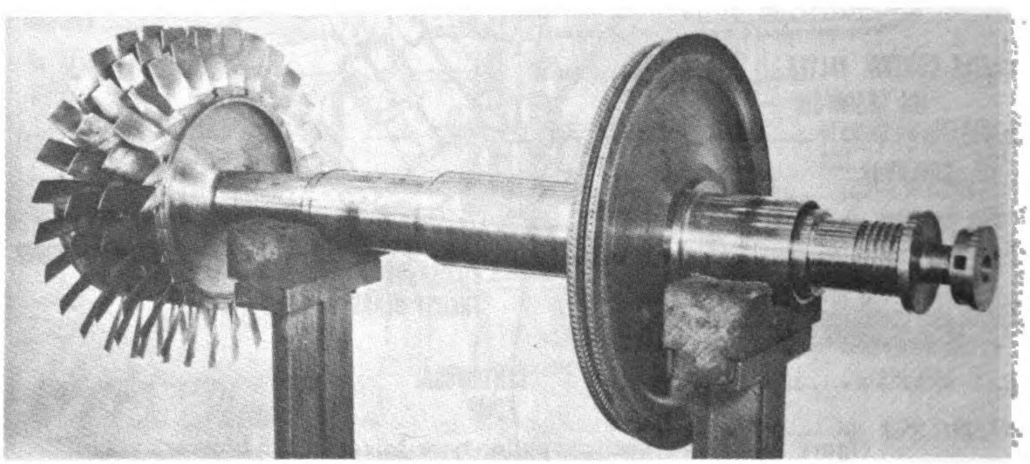


Figure 7–3.—Three-stage propeller for vertical blower.

flange of the outer casing, which is bolted to the ship's structure. Guide vanes, which direct the flow of air, are installed between the inner and the outer blower casings. The inner casing is welded to the upper half of the turbine casing. The lower part of the turbine casing is welded to the oil reservoir casing. The oil reservoir contains the lower radial bearing and a thrust bearing.

The propeller-type fan is made of forged steel; it is welded to the hub, which is fitted to the turbine shaft. The blower

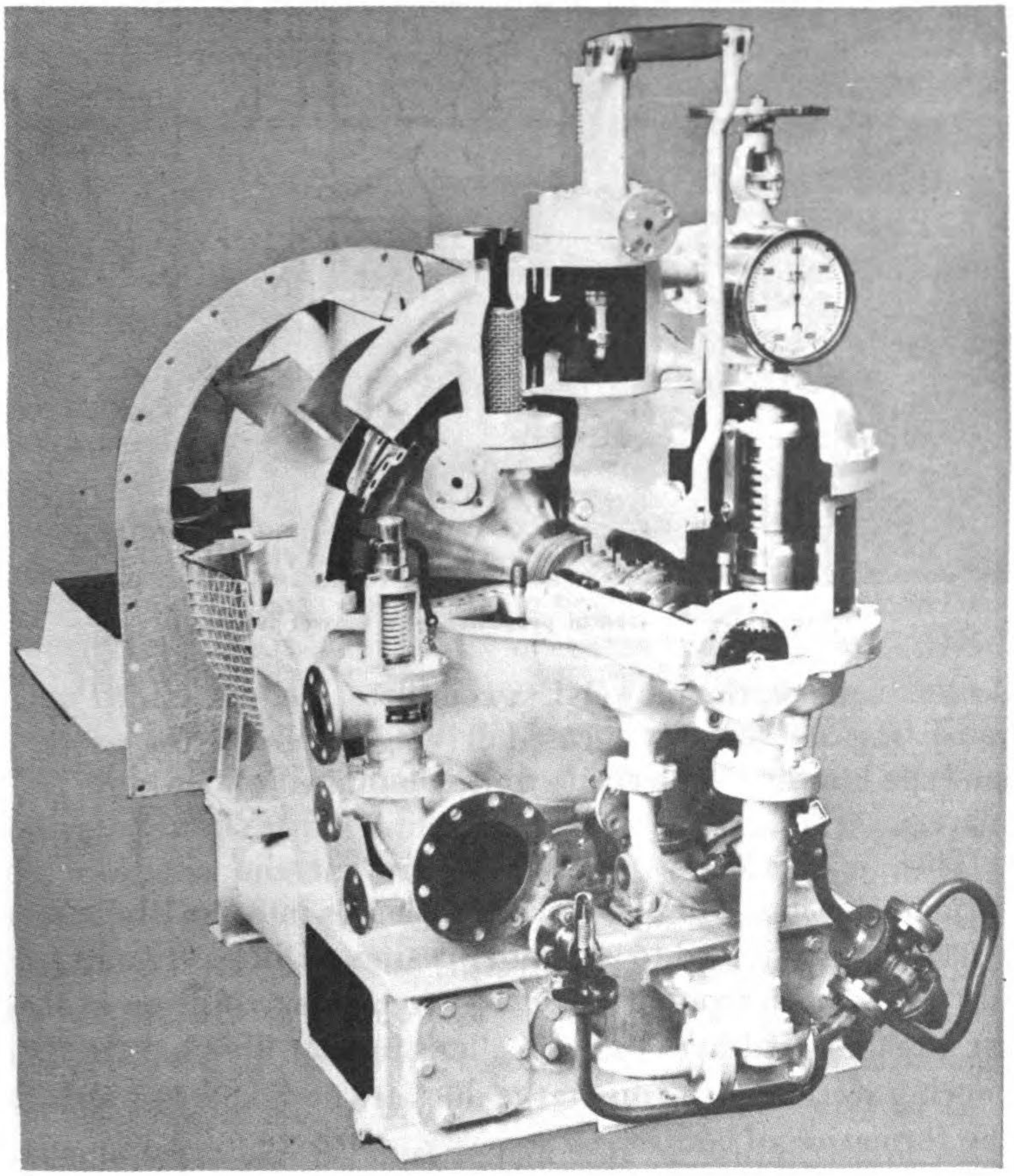


Figure 7–4.—Horizontal propeller-type blower (view I).

shown in figure 7–2 has only one propeller, but two-stage and three-stage blowers are also used. Figure 7–3 shows a three-stage propeller for use in a vertical turbine-driven blower.

Horizontal propeller-type blowers similar to the one shown in figures 7–4 and 7–5 are commonly used on combatant ships.

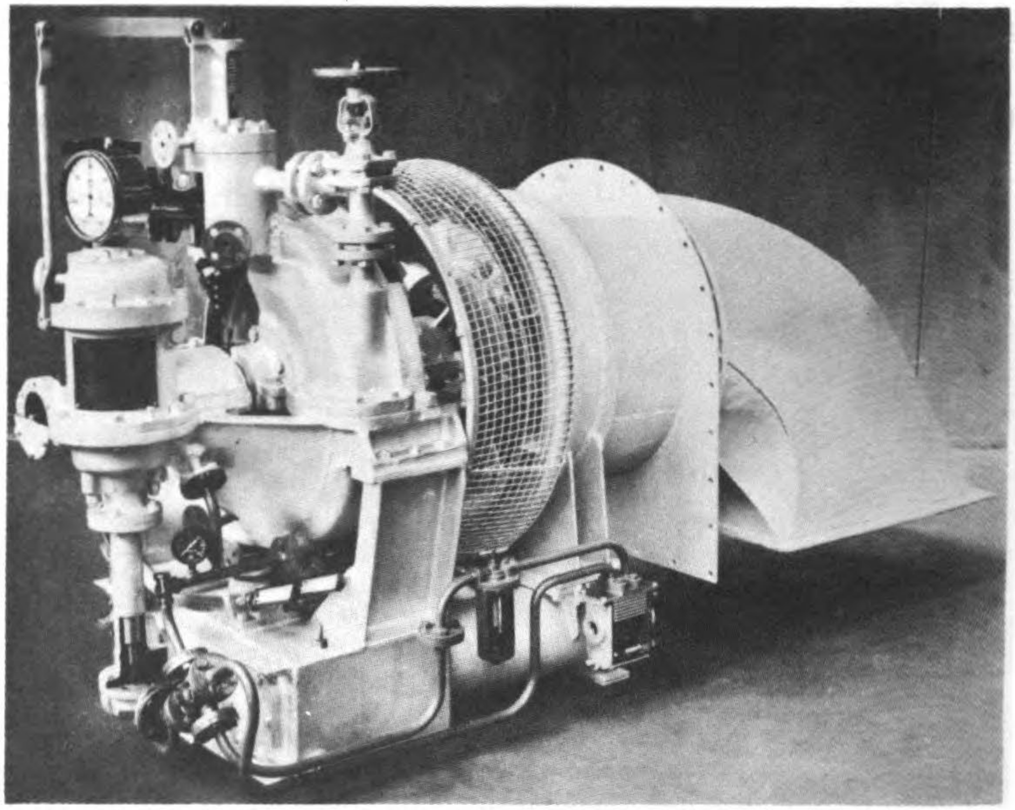


Figure 7–5.—Horizontal propeller-type blower (view II).

As you can see, the blower is a complete, self-contained unit consisting of a suitably encased driving turbine and a propeller-type blower. The entire unit is mounted on a single bed plate.

The air intake is screened to prevent the entrance of foreign objects. The blower casing merges into the discharge duct, which is joined to the boiler casing. Diffuser vanes are installed just in front of the blower to prevent rotation of the air stream as it leaves the propeller; further divisions in the curving section of the discharge duct are designed to prevent the formation of eddies.

The shaft, which carries both the propeller and the turbine

rotor, is a single forging. The propeller is keyed to the shaft and is held to the tapered shaft end by a nut and a cotter pin. The turbine rotor is keyed to the shaft. The entire assembly is supported by two bearings, one on each side of the rotor, outside the turbine casing. The governor-end bearing is located in the governor housing, which also contains a thrust bearing.

The speed-limiting governor spindle and the lubricating oil pump shaft are driven by the main shaft, through a reduction gear.

CONTROL OF BLOWER SPEED

Blowers used on naval vessels are manually controlled. Speed-limiting governors are fitted to all forced draft blowers, but they function only as safety devices to prevent the turbine from exceeding a maximum safe operating speed; they do not have any control over the turbine at ordinary operating speeds. Two types of speed-limiting governors are commonly used on forced draft blowers: the centrifugal-weight type, and the oil-pressure type. These governors are described in the chapter on auxiliary turbines.

Manual control of blower speed is achieved by a valve arrangement which controls the amount of steam admitted to the turbines. In some blowers, a full head of steam is admitted to the steam chest; steam is then admitted to the turbine by means of a manually-operated lever or hand wheel which controls four nozzle valves. (The lever or hand wheel may be connected by linkage for remote operation.) The four valves are so arranged that they open in succession, rather than all at the same time. The position of the manually operated lever or hand wheel determines the number of valves which will open, and so controls the amount of steam which will be admitted to the turbine. The steam chest nozzle valve shafts of all blowers serving one boiler are mechanically coupled so as to provide for synchronized operation. If only one blower is to be operated, the root valve of the nonoperating blower must remain closed so that steam will not be admitted to the line.

In other installations, a throttle valve is used to control the admission of steam to the steam chest. From the steam chest, the steam enters the turbine casing through fixed nozzles, rather than through nozzle valves. Varying the opening of the throttle valve varies the steam pressure to the chest, and so varies the speed. The same throttle valve is usually used to control the admission of steam to all blowers serving any one boiler. If only one blower is to be operated, the root valve of the other must be kept closed.

When admission of steam is controlled by the four nozzle valves, no additional nozzle area is required to bring the blower up to maximum speed. In the other type of installation, however, a special hand-operated nozzle valve is provided for high-speed operation. This nozzle valve, which is sometimes called an OVERLOAD NOZZLE VALVE, is used when it is necessary to increase the blower speed beyond that obtainable with the fixed nozzles. As a rule, the use of the overload nozzle valve is required only when steam pressure is below normal.

LUBRICATING OIL SYSTEMS

Because forced draft blowers must operate at very high speeds, correct lubrication of the bearings is absolutely essential. A complete lubricating oil system for supplying oil to the bearings is an integral part of the unit. Most forced draft blowers have two radial bearings and one thrust bearing; however, you may find some blowers which have two turbine bearings, two fan bearings, and a thrust bearing.

The lubrication system for a horizontal blower usually consists of a simple gear pump, an oil filter, an oil cooler, a filling connection, relief valves, oil level indicators, thermometers, pressure gages, oil flow sights, and appropriate piping.

The positive-displacement gear pump is run by the main shaft, but it is geared down to about one-fourth of the speed of the turbine. The lubricating oil is pumped from the oil reservoir, through the oil filter and the oil cooler, to the bearings. Oil then drains back to the reservoir by gravity,

through drain lines which are equipped with oil flow sights, thermometers, and breathers.

Some vertical blowers are fitted with a positive-displacement gear pump and a lubrication system which is generally similar to that just described for horizontal blowers. However, many vertical blowers have a different type of lubrication system in which the simple gear pump is replaced by a centrifugal pump and a helical-groove viscosity pump. The centrifugal pump impeller is on the lower end of the main shaft, just below the lower radial bearing. The viscosity pump (sometimes called a FRICTION PUMP) is on the shaft, inside the lower half of the lower bearing, just above the impeller.

The general arrangement of this type of lubrication system is shown in figure 7–6. As you can see, the oil is delivered to the lower bearing; and from there it goes, by way of a hole in the shaft, to the upper bearing. In addition, part of the oil is pumped directly to the upper bearing through an external supply line (not shown in figure 7–6). The oil is returned from the upper bearing to the oil reservoir, through an external pipe.

In this system, unlike the system previously described, the lubricating oil does NOT go through the oil strainer or the oil cooler on its way to the bearings. Instead, oil from the reservoir is constantly being circulated, through an external filter and a water-cooled oil cooler, back to the reservoir. Sea water for the cooler is taken from the regular cooling water system or, through a pressure-reducing valve, from the firemain.

In this type of lubricating oil system, a viscosity pump is used to supply oil to the bearings when the blower is operating at low speed. The viscosity pump is essentially a shallow, helical groove or thread on the lower shaft, inside the lower bearing shell. As the shaft rotates, the oil is picked up in the shallow groove and is carried to the hole in the shaft which leads to the upper bearing. The viscosity pump is necessary because the pumping action of the centrifugal impeller is dependent upon the rpm of the shaft; and at low

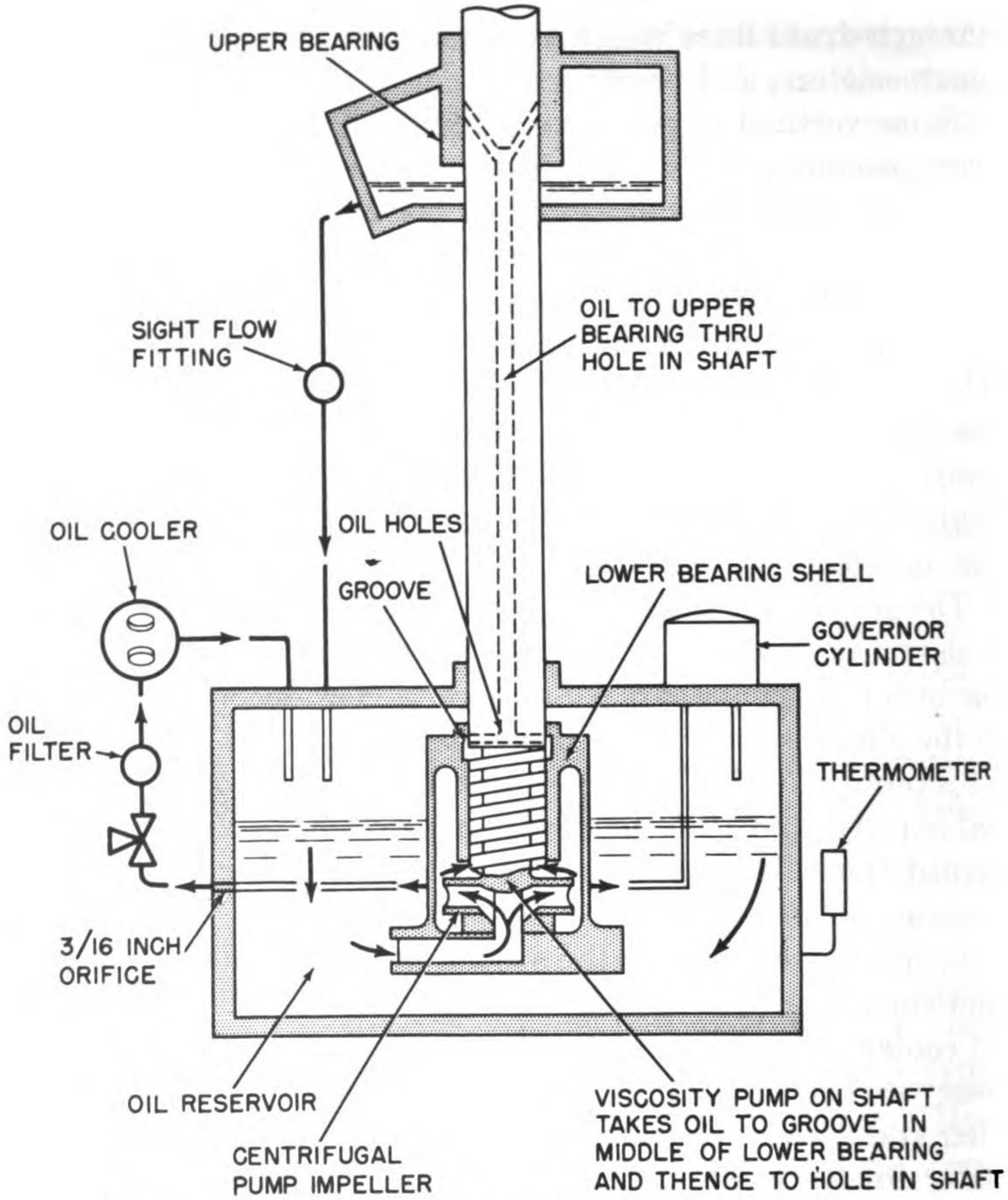


Figure 7–6.—Lubrication system for vertical forced draft blower.

speed the centrifugal pump cannot develop any appreciable oil pressure.

When the blower is operating at high speed, the centrifugal pump provides more pressure than is needed for lubrication. Under these conditions, the viscosity pump serves to limit the pressure at which oil is delivered to the bearings. This function is an important one, since excessive oil pressure would cause flooding of the bearings, with consequent loss of oil from the lubricating system.

A system of air balancing is generally used to equalize air pressures between the oil side of a bearing and its outer housing, so that oil will not be drawn into the air stream and thus be lost from the lubrication system.

TACHOMETERS

Many forced draft blowers are fitted with constant-reading, permanently-mounted tachometers for determining blower speed. Sometimes the tachometer is mounted on top of the governor and is driven by the governor spindle. The governor spindle is driven by the main shaft through a reduction gear, and therefore does not rotate at the same speed as the main shaft; however, its rpm is proportional to the rpm of the main shaft, and the tachometer is calibrated to give main shaft readings.

Resonance tachometers—either permanently-mounted or portable—are frequently used on forced draft blowers. As mentioned in chapter 4, the resonance tachometer must be clamped firmly to the foundation or to the casing of the blower.

Some blowers of recent design are equipped with an unusual type of tachometer called a PRESSURE-GAGE TACHOMETER. This instrument is actually a pressure gage which is calibrated in both psi and rpm. It depends for its operation upon the fact that the oil pressure built up by the centrifugal lube oil pump has a definite relation to the speed of the impeller; and the speed of the impeller is, of course, determined by the speed of the main shaft. Thus, the instrument can be calibrated in both psi and rpm. This type of tachometer is tested on an ordinary dead-weight pressure gage tester.

From time to time you may have to use portable tachometers to check the speed of forced draft blowers. On most horizontal blowers, the portable tachometer can be applied directly to the end of the main shaft. On vertical blowers the procedure must be somewhat different, since you can't get at the end of the main shaft. On many vertical blowers a separate, small shaft is fitted so that readings may be taken

with a portable tachometer. The small shaft is driven by the main shaft, through gearing; it may rotate at the same speed as the main shaft, or its speed may be reduced by the gear arrangement. If the small shaft is rotating at a speed different from that of the main shaft, you must, of course, convert your tachometer reading in order to get the speed of the main shaft.

The stroboscopic tachometer is sometimes used to measure the rpm of a forced draft blower. When the instrument is adjusted so that a mark on the main shaft of the blower appears motionless, the rpm of the shaft may be read directly from the control dial of the tachometer.

FORCED DRAFT BLOWER OPERATION

The following instructions for the operation of forced draft blowers are general in nature. They should be supplemented by the specific instructions issued by the manufacturer, for the blowers installed on your ship.

In general, the procedure for starting a forced draft blower is as follows:

1. Follow all appropriate instructions for the operation of the blower turbine. (See the chapter in this book on auxiliary turbines.)
2. Examine the fan; make sure that it is free of dirt, tools, waste, etc. Check the blower room to be sure that there are no loose objects lying around which might be drawn into the fan when the blower is started.
3. Move the flaps or automatic shutters by hand, to be sure that they are not locked. Leave the shutters closed—but not locked—so that they will open automatically when the blower has built up enough pressure. CAUTION: Do NOT try to move flaps or shutters by hand if another blower serving the same boiler is already in operation.
4. When only one blower on a boiler is to be operated, check to be sure that the automatic shutters on the idle blower are closed.

5. On a centrifugal-type blower, turn the fan by hand. It should revolve easily and quietly.
6. Check the oil level in the reservoir; if necessary, add oil of the proper type. Rotate the handle of the oil filter.
7. Lubricate the linkage and slides on the speed-limiting governor. Make sure that the speed-limiting governor is free and operable. If an overspeed trip is installed, set it and trip it by hand.
8. Open the inlet and exhaust drains.
9. Open the turbine exhaust valve.
10. Open the steam supply root valves. If only one blower is to be operated, be SURE that the steam supply root valve to the idle blower is closed.
11. Admit steam to the turbine by cracking the throttle valve, and gradually bring the blower up to the required speed.
12. When the unit has warmed up, close the inlet and exhaust drains.
13. When the oil leaving the bearings reaches a temperature of 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit the operating conditions.

The pressure gage in the lubricating oil system must be checked while the blower is being started up, and at frequent intervals during the period of operation. Watch the pressure gage carefully while the blower is starting up, to be sure that proper oil pressure is being developed. When the unit has been brought up to speed and the oil has become warm, check the oil pressure against the correct pressure for that particular speed, as given in the manufacturer's instruction book.

The temperature of the oil leaving the bearings should be checked frequently. Under normal operating conditions, the temperature of the oil leaving the bearings should be between 140° and 160° F; it should never be permitted to exceed 180° F. The temperature rise of the oil through any bearing should not exceed 50° F.

Blower speed, oil pressure, and the highest temperature of oil leaving any bearing must be entered in the fireroom log every hour.

The general procedure for securing a forced draft blower is as follows:

1. Close the steam throttle valve and the steam supply root valve.
2. Close the exhaust valve at the blower; if a root exhaust valve is installed, however, keep it open.
3. Open the drain valves.
4. Check to be sure that the flaps or automatic shutters are closed.
5. Secure the cooling water to the oil cooler.
6. Close the drain valves after all steam and condensate has been drained off and the casing has cooled down to blower room temperature.

CARE AND MAINTENANCE OF BLOWERS

Forced draft blowers require relatively little maintenance or repair, under normal operating conditions, provided they are adequately lubricated at all times. Much of your maintenance work on blowers will be concerned with keeping the lubrication system in proper condition.

The lubricating oil in the reservoir must be kept clean, and the reservoir must always be filled to the proper level with oil of the specified weight and grade. An oil sample should be taken routinely about once a week, and oftener if you suspect that the oil is contaminated. When the sample shows an undue amount of sediment or water, this fact should be reported to the engineering officer or to the Chief in charge, who may issue instructions to change the oil. After the old oil has been drained, the inside of the reservoir should be wiped clean. Inspection plates allow access to the inside of the reservoir.

The edge-filtration type of filter should be cleaned at least once each watch; this is done by giving the handle one or two complete turns. At regular intervals, the filter should be dismantled and cleaned with an approved cleaning fluid; this

should be done at least every time the oil is renewed in the reservoir, and oftener if necessary.

The oil cooler requires occasional cleaning and repair. In the lubrication system which utilizes a simple gear pump, all oil normally passes through the cooler on its way to the bearings. However, a four-way valve installed in the oil supply line ahead of the cooler makes it possible to isolate the cooler for inspection, cleaning, repair, or replacement. (CAUTION: When putting the cooler back into the system, be sure that the four-way valve is in the proper position to allow oil to flow through the cooler.)

In the other type of lubrication system, where oil is continuously circulated through the filter and the cooler and back to the reservoir, a cut-out valve is installed in the line just ahead of the filter so that the filter and the cooler may be isolated.

Automatic shutters are not subject to any great amount of wear, under normal operating conditions, and will seldom require repair. However, they MUST be kept well lubricated at all times. Some types of shutters have Zerk grease fittings; others have oil holes. Be sure to use the correct lubricant.

If the automatic shutters are not properly lubricated, they may stick in the open position and then slam shut with sufficient force to cause damage to shutters and toggle gear. Broken or sprung parts must be replaced to ensure smooth operation of the shutters.

Certain routine tests and inspections must be made in order to keep a check on the general condition of all forced draft blowers. Idle blowers should be turned by hand once a day, and an entry should be made in the appropriate check-off list or log. Automatic shutters should also be moved by hand once a day. After each period of steaming (and, in any case, at least once each quarter) all blower units and foundations should be carefully inspected, and loose or broken rivets, nuts, and bolts should be tightened or renewed.

Forced draft blowers should be carefully observed during operation, and should not be run if there is excessive vibra-

tion or unusual noise. Vibration may be caused by worn or loose bearings, a bent shaft, loose or broken foundation bolts or rivets, an unbalanced fan, or other defects. Such defects should be remedied as soon as possible, in order to prevent a complete breakdown of the blower unit.

Minor repairs to blower fan blades may be made on board ship in case of emergency, but major repairs cannot be made without special instructions from the Bureau of Ships. As a matter of routine maintenance, blower fans should be wiped down from time to time, to remove dirt and dust. Paint must NEVER be applied to a blower fan, or to any other rotating part of the unit.

Care and maintenance of turbines used to drive forced draft blowers is discussed in the chapter on auxiliary turbines.

SAFETY PRECAUTIONS

The following safety precautions should be observed in connection with the operation of forced draft blowers:

1. Before starting a blower, always make sure that the fan is free of dirt, tools, rags, and other foreign material.
2. Do not try to move automatic flaps or shutters by hand if another blower serving the same boiler is already in operation.
3. When only one blower on a boiler is to be operated, make sure that the automatic shutters on the idle blower are closed.
4. Never try to turn a blower by hand when steam is being admitted to the unit.
5. Never tie down the speed-limiting governor. Be sure that it is in good operating condition at all times. Be sure that it is properly set.
6. Observe all appropriate safety precautions concerning turbine operation.

QUIZ

1. What kind of drive is most commonly used for forced draft blowers?
2. In the open-fireroom type of forced draft blower installation, where do the blowers take suction?
3. Why is it important to prevent forced draft blowers from being rotated in reverse?
4. When a blower is idle, what is the proper position of the automatic shutters or flaps?
5. With respect to the movement of air, what is the main difference between centrifugal-type and propeller-type blowers?
6. Which type of blower loses its load and tends to overspeed when either the intake damper or the discharge damper is closed?
7. What is the function of the governors used on forced draft blowers?
8. What two types of governors are commonly used on forced draft blowers?
9. When a throttle valve is used to control the admission of steam to the steam chest, what device is used when it is necessary to run the blower at a higher speed than that which can be obtained by means of the regular fixed nozzles?
10. What types of pumps are used in the lubrication systems of forced draft blowers?
11. What two purposes are served by a viscosity pump?
12. When starting a forced draft blower, at what point should you cut in the cooling water to the oil cooler?
13. Under normal operating conditions, what is the temperature of the lube oil leaving the bearings?
14. How often should the edge-filtration type of oil filter be cleaned by rotation of the handle?
15. How frequently should idle blowers be turned by hand?

CHAPTER 8

BOILER WATER TREATMENT

An important part of your job as a Boilerman is to make sure that the water in the ship's boilers meets certain requirements. You must know how to determine the chloride content, hardness, and alkalinity of boiler water, and you must know how to treat the boiler water in order to maintain it within the prescribed limits. The correct treatment of boiler water is important in any type of boiler, but it is particularly important in modern, high-pressure boilers (600 psi and above).

BOILER WATER PROBLEMS

All boiler water contains some impurities. Most of the soluble impurities present in boiler water are derived from sea salts, particularly sodium chloride (common table salt), magnesium chloride, magnesium sulphate, calcium sulphate, and calcium carbonate. Other impurities present in boiler water may include dissolved oxygen, oil, chemicals used in the treatment of boiler water, and insoluble corrosion products such as rust. Impurities dissolved or suspended in boiler water can cause trouble in the following ways:

1. By forming scale deposits on boiler watersides
2. By forming sludge
3. By causing corrosion of boiler watersides
4. By causing foaming and excessive carry-over.

Scale

The formation of scale on boiler watersides is caused primarily by certain magnesium and calcium salts which are not so soluble at high temperatures as they are at lower temperatures. Since these substances are present in sea water, and since all feed water is distilled from sea water, some slight contamination of the feed water must always be expected.

When scale-forming salts are present, the water is said to be HARD. Although a very slight amount of hardness may be tolerated in the feed water, the water in the boiler must be free of hardness in order to prevent the formation of scale. The proper use of Navy boiler compound will maintain boiler water at zero hardness.

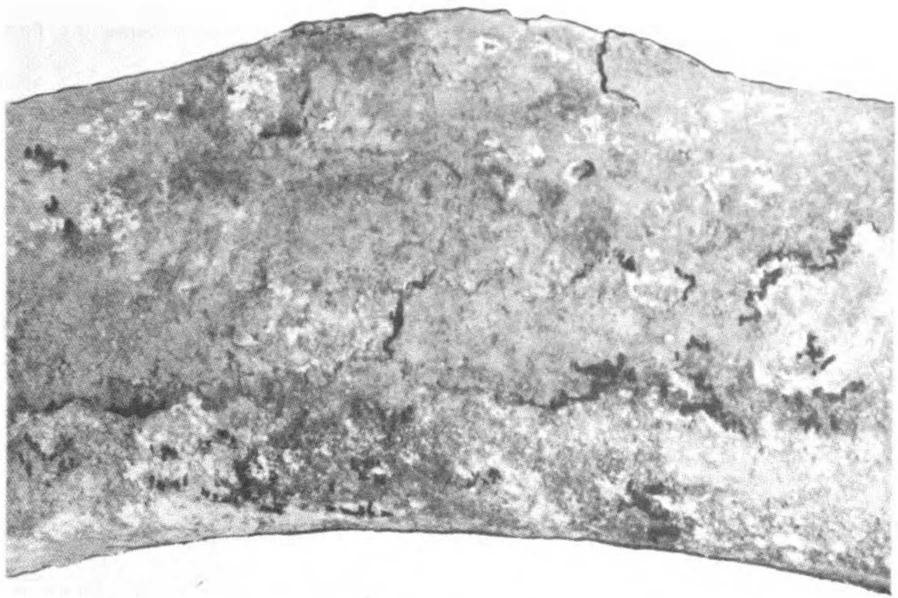


Figure 8–1.—Overheat blister on boiler tube.

Scale deposited on boiler watersides retards the transfer of heat to the boiler water, and thus causes a rapid rise in the temperature of the tube metal. In other words, the scale in the tube prevents the water from carrying heat away as

rapidly as it is applied. The excessive heat causes the tube to blister, or even to rupture. Figure 8–1 shows a boiler tube which has blistered because of waterside scale deposits.

Sludge

A certain amount of suspended solid matter accumulates in the boiler water. This material consists chiefly of (1) corrosion products, such as metal oxides; and (2) Navy boiler compound and its reaction products. The corrosion products tend to settle into the lower drums and headers, but the other suspended matter circulates with the boiler water as long as it is present in relatively small amounts.

As the amount of suspended matter increases, however, deposits of sludge will gradually be laid down in the lower drums and headers and in the boiler tubes, where it may become baked. Baked sludge is difficult to detect and extremely hard to remove. If it is not removed, the sludge acts in much the same way as scale to interfere with heat transfer and thus cause overheat blisters.

Blowdown should be used to prevent excessive accumulation of suspended matter in the boiler water, and thus to prevent deposits of baked sludge. It is important to remember that neither blowdown nor treatment with Navy boiler compound will remove deposits of baked sludge. The importance of preventing the accumulation of sludge may be indicated by the fact that approximately 25 percent of all boiler tube casualties are associated with such deposits.

Corrosion

Corrosion of boiler watersides will occur if the boiler water is not kept at the proper alkalinity or if the boiler water contains dissolved oxygen.

General corrosion may be caused by low alkalinity. This type of corrosion is indicated by a fairly even and widespread etching of the waterside surfaces. In some instances, general corrosion may be accompanied by localized pitting.

Furrowing or grooving of boiler tube metal may result

from excessive alkalinity of the boiler water. The danger of this type of corrosion is particularly great in the fire-row and stud-row tubes, where high evaporation rates sometimes lead to the development of unusually strong caustic concentrations. The caustic action dissolves the protective layer of oxide from the surface of the metal, and thereby allows the repeated formation and solution of metal oxides.

One of the most serious types of boiler watersides corrosion is known as OXYGEN PITTING (fig. 8–2). The presence of dissolved oxygen in the water causes deep pits, which may

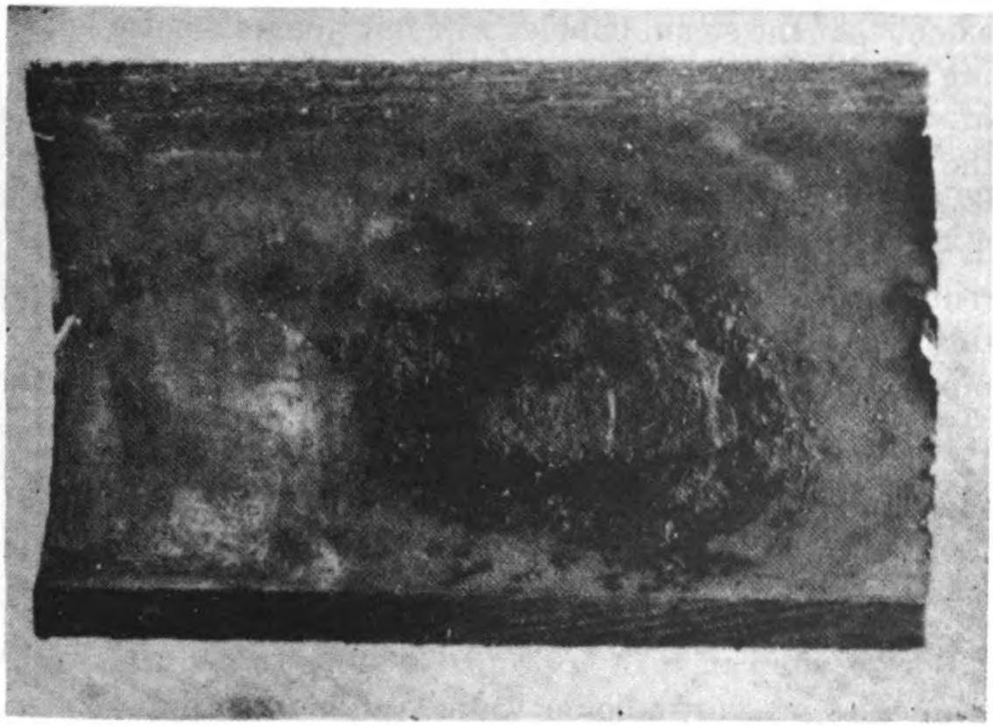


Figure 8–2.—Internal pitting of boiler tube.

eventually extend all the way through the tube wall. In modern feed systems, a deaerating feed tank is used to remove oxygen from the feed water before it enters the boiler, and tests are made to determine the amount of dissolved oxygen present in the feed water when it leaves the deaerating feed tank. The deaerating equipment and the procedure for making dissolved oxygen tests of the feed water are described in the following chapter on feed water systems.

Foaming and Carry-Over

The presence of impurities in boiler water may cause abnormal boiling conditions which will lead to the troubles known as foaming and carry-over.

FOAMING is the term used to describe the formation of froth or bubbles when water is boiled. A high concentration of impurities in the boiler water is almost certain to cause foaming. Boiler water that is contaminated with oil will foam excessively when boiled.

If the boiler water contains large amounts of suspended or dissolved impurities, the foam may be stabilized to such an extent that the steam bubbles will fail to break before entering the dry pipe. If the bubbles do not break, small particles of water (containing the same impurities that are present in the boiler water) will be carried along with the steam. This water, which is known as CARRY-OVER, may be extremely damaging to the superheater. Carry-over causes a rapid reduction in the temperature of the superheated steam, and this change in temperature may cause damage to the steam pipes and to all machinery operated by superheated steam.

Excessive carry-over is prevented by (1) minimizing contamination of boiler water, and (2) using surface and bottom blows to remove dissolved and suspended solids.

BOILER WATER ANALYSES

Before you can take appropriate steps to counteract the impurities present in boiler water, you must know the alkalinity, hardness, and chloride content of the water. This information is obtained by means of boiler water analyses.

Units for Reporting Water Analyses

In the past, water analyses were reported in various units such as grains per gallon, percent normal, and milliliters per liter. However, the Navy has recently adopted a standard system for reporting water analyses, and this system MUST be used.

All boiler water tests, and all feed water tests except the

test for dissolved oxygen, are reported in terms of a unit called EQUIVALENTS PER MILLION. The dissolved oxygen content of feed water is reported in terms of a unit called PARTS PER MILLION. It will be easier to understand EQUIVALENTS PER MILLION if you first understand PARTS PER MILLION.

PARTS PER MILLION is a weight-per-weight unit denoting the number of parts of a specified substance in a million parts of water. For example, 58.5 pounds of salt in 1,000,000 pounds of water represents a concentration of 58.5 parts per million (ppm). Note, also, that 58.5 *ounces* of salt dissolved in 1,000,000 *ounces* of water, or 58.5 *tons* of salt dissolved in 1,000,000 *tons* of water, represent the same concentration—that is, 58.5 ppm. Similarly, 8 pounds of oxygen dissolved in 1,000,000 pounds of water represents 8 ppm.

EQUIVALENTS PER MILLION can be defined as the number of EQUIVALENT parts of a substance per million parts of water. (The word "equivalent" here refers to the chemical equivalent weight of a substance.) The chemical equivalent weight is different for each element or compound. The chemical equivalent weight of sodium chloride (common table salt) is 58.5. A solution containing 58.5 PARTS PER MILLION of this salt is said to contain 1 EQUIVALENT PER MILLION. If a substance has a chemical equivalent of 35.5, a solution containing 35.5 parts per million is described as having a concentration of 1 epm.

All water tests performed on board ship could be expressed in equivalents per million. However, the standard system requires that alkalinity, hardness, and chloride content be expressed in epm but that dissolved oxygen be expressed in ppm. (For discussion of the dissolved oxygen test, see the chapter on feed water systems.)

Hardness, Alkalinity, and Chloride Limits

Boiler water should be maintained at ZERO HARDNESS.

The ALKALINITY of boiler water should be between 2.5 epm and 3.5 epm. In certain instances, deviations from these limits may be authorized by the Bureau of Ships. Low alkalinity may permit general corrosion to take place, while high

alkalinity may cause furrowing and grooving. Thus it is important to maintain boiler water at the correct alkalinity—neither too low nor too high.

The CHLORIDE CONTENT of boiler water should be as low as possible. The MAXIMUM chloride concentration permitted for boilers having tubes less than 2 inches in diameter is 15 epm. For large-tube boilers, the maximum allowable concentration is 25 epm.

Frequency of Boiler Water Tests

The following tests must be made of boiler water, and the results entered in the appropriate record sheet or log:

STEAMING BOILERS.—Alkalinity, chloride, and hardness must be tested DAILY. In addition, appropriate tests must be made after boiler compound has been added and after blowdown.

NEWLY FILLED BOILER.—Alkalinity, chloride, and hardness must be tested immediately after the boiler is filled, and again after the boiler is steam tested.

IDLE BOILERS.—Alkalinity, chloride, and hardness must be tested WEEKLY.

Boiler Water Testing Cabinet

All of the equipment necessary for making the required boiler water tests is assembled in the Navy standard boiler water testing cabinet, shown in figure 8–3.

The following items are included in the boiler water testing cabinet:

1. Three 1-liter bottles, one for each of the reagents—nitric acid, mercuric nitrate, and soap solution. A 10-milliliter (ml) automatic-zero burette and an aspirator bulb are fitted into the stopper of each reagent bottle.
2. Three 60-milliliter (ml) bottles (with droppers)—one for methyl-purple indicator, one for phenolphthalein indicator, and one for chloride indicator.
3. Two porcelain casseroles.
4. One 100-milliliter (ml) graduated cylinder.

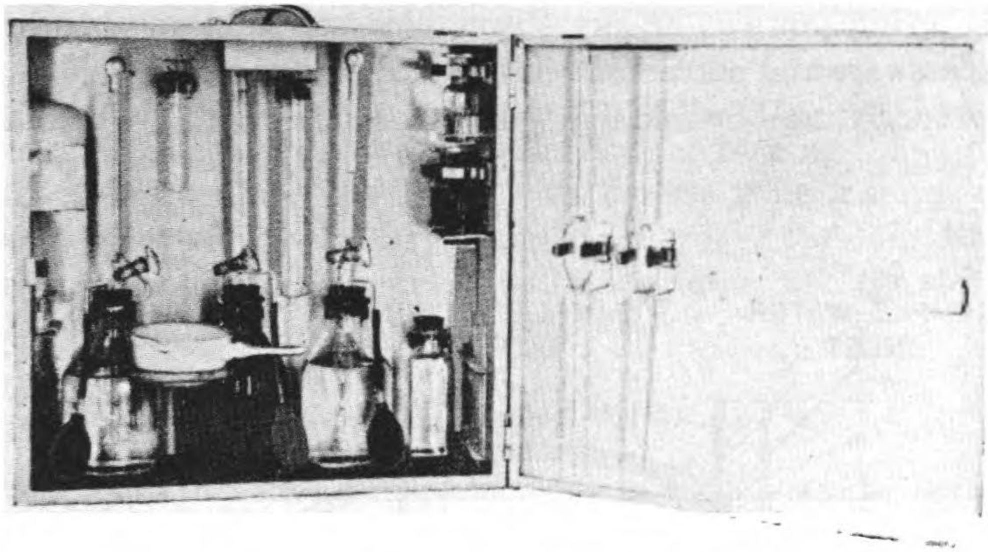


Figure 8–3.—Boiler water testing cabinet.

5. One 10-milliliter (ml) graduated cylinder.
6. Two 50-milliliter (ml) pipettes.
7. Six stirring rods.
8. One 8-ounce, square bottle for hardness test.
9. One collapsible tube of stopcock grease.
10. Solid stoppers for reagent bottles, for use when mixing test solutions.

Reagents for use in the various water tests are generally supplied as standard stock solutions at 10 or 20 times the required strength. These stock solutions must be diluted to the proper strength with double-distilled water or alcohol, as appropriate, using the measuring equipment provided in the boiler water testing cabinet. Full instructions for the preparation of these solutions may be found in chapter 56, BuShips *Manual.*

The boiler water testing equipment must be kept scrupulously clean at all times. If it is not kept clean, the results of the water tests will not be accurate. The soap-solution burette can be cleaned with distilled water or with alcohol. The dishes, pipettes, and graduated cylinders should be rinsed in distilled water immediately after each use. Soap may be used, if necessary, to wash this equipment, but it must be completely removed by thorough rinsing. Never use lye,

scouring powder, or any strong cleanser to clean chemical glassware and porcelain. If soap and water will not clean it properly, use a weak acid solution; but BE SURE to rinse all the acid off.

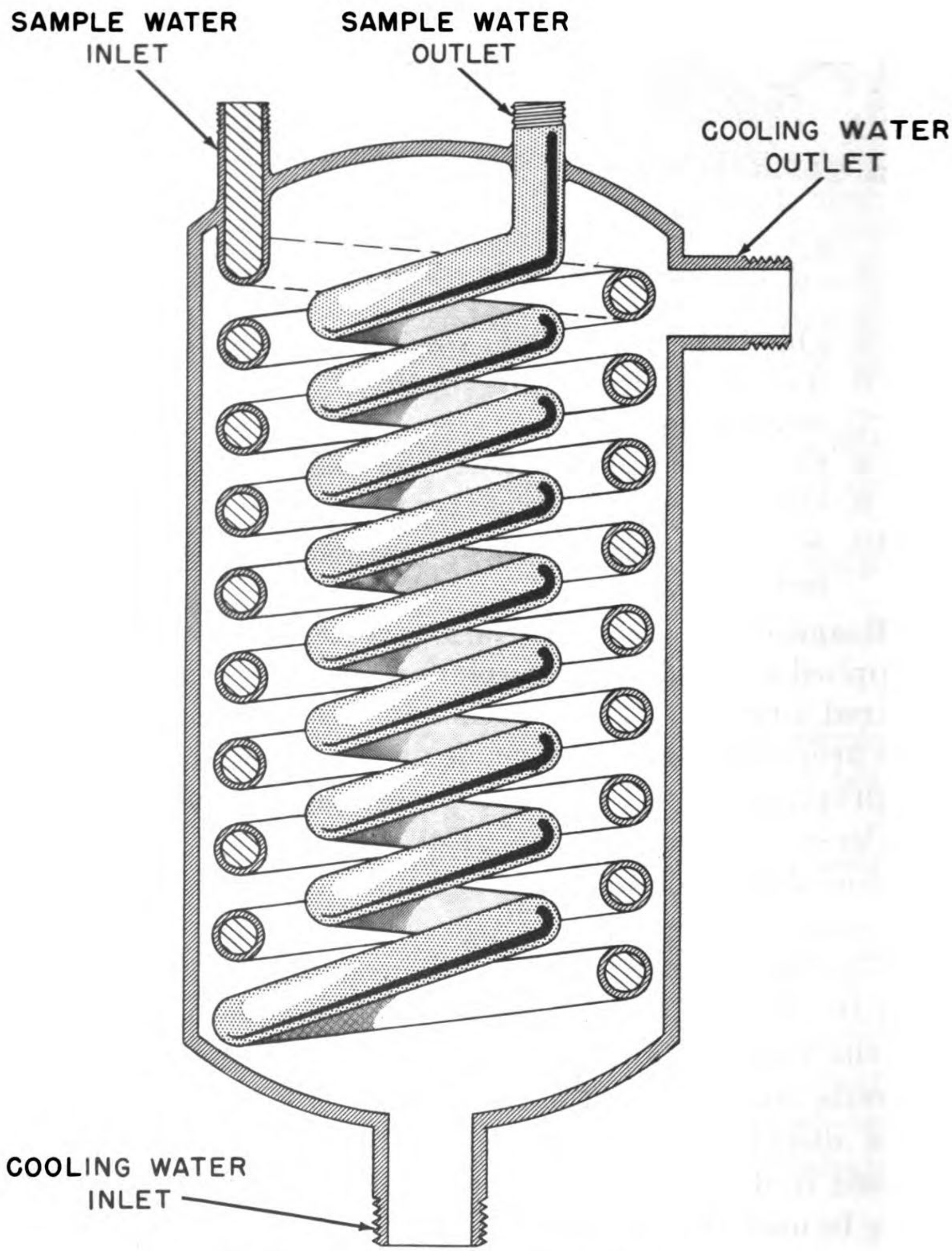


Figure 8–4.—Boiler water sample cooler.

The burette stopcocks must be lubricated occasionally. Use the special stopcock grease provided.

When using the water testing equipment, do not exert any pressure on the burette tip, especially when turning the stopcock. Do not attempt to remove a burette from a stopper, except when it is necessary to replace a broken burette. Before a new burette is inserted, both the stopper and the stem of the burette should be thoroughly wet.

Sampling Boiler Water

Samples of boiler water taken for analysis must be truly representative of the water in the boiler. The container into which the sample is drawn must be clean, and the sampling connection must be thoroughly flushed out to remove sediment and stagnant water which may be trapped in the line or in the connection.

The water sample must be protected from contamination during the interval between sampling and analysis. It must not be exposed to the air, since an alkaline sample would absorb carbon dioxide from the air; this would result in a false, low reading for alkalinity.

Boiler water samples should be cooled down to below 100° F before being tested. On high-pressure boilers, a cooling coil of the type shown in figure 8–4 is provided in the sampling line. If no provision is made for cooling the water, as much as one-third of the sample may flash into steam and be lost. If such a sample is tested, the results will not reflect the true condition of the water in the boiler.

Testing for Alkalinity

There are two methods of testing for alkalinity. The PHENOLPHTHALEIN test is used for water from steaming boilers and for water from idle boilers which have been steamed. The METHYL-PURPLE test is used for water in freshly filled boilers which have not been steamed. If a boiler has been idle for a long time, it is best to use both tests.

The phenolphthalein test for steaming boilers and for idle boilers is performed as follows:

1. Take a sample of boiler water.
2. Rinse a 100-ml graduated cylinder with some of the test water, and use the graduate to transfer 50 milliliters of the water to a porcelain casserole. Be sure the casserole is clean.
3. Add two or three drops of phenolphthalein indicator. If the sample is alkaline, the water will turn a deep pink color.
4. Fill the automatic-zero burette to its tip with nitric acid solution. Refill it, and allow it to drain down to zero.
5. Add the acid solution from the burette to the sample, while stirring the sample continuously. Add only one drop at a time. The pink color will begin to fade, and will eventually disappear.
6. When the pink color has just disappeared, read the burette. The burette is calibrated in milliliters, but the reading is numerically the same as equivalents per million. Thus, a burette reading of 2.6 ml represents an alkalinity of 2.6 epm. CAUTION: The reading should be made at the BOTTOM of the meniscus (curved surface of the liquid).

The methyl-purple test for freshly filled boilers is performed as follows: Measure 50 ml of sample water into the porcelain casserole, and add two drops of methyl-purple indicator. If the sample is alkaline, the water will turn green. Stirring the sample, add reagent acid solution until the color changes to purple. A gray tint precedes the purple end point color, and serves as a warning of its approach. As soon as the color of the sample changes from green to purple, record the reading of the burette. The color change is quite easily seen in clear water; but if the water is red with suspended iron compounds, a greenish-gray color frequently persists between the green and the purple, rendering the end point difficult to ascertain.

If it is impossible to obtain a clear sample for the methyl-

purple test, an approximate value for the total alkalinity may be obtained by making a phenolphthalein test and multiplying the result by two.

Testing for Hardness

Water in which soap does not readily form a lather is said to be HARD. The hardness is due to the presence of certain dissolved salts. Since these salts form scale in boilers, you can see why boiler water should be at zero hardness.

The hardness of boiler water is found by the following procedure:

1. Use the 100-ml graduated cylinder to transfer 50 milliliters of the water sample to the square, 8-ounce bottle.
2. Fill the burette to its tip with soap solution. Refill it, and let it drain down to zero.
3. From the burette, add to the sample an amount of soap solution equal to the LATHER FACTOR. The lather factor, which should be marked on the bottle, is the amount of soap solution required to produce a lather in double-distilled water. A lather, in this connection, is defined as one which will entirely cover the surface of the water and persist for five minutes. The lather factor must be determined for each new lot of reagent soap solution. Chapter 56, BuShips *Manual*, gives detailed instructions for preparing the soap solution and determining the lather factor.
4. Stopper the bottle and shake it vigorously.
5. Lay the bottle on its side and start a stop watch.
6. If the lather persists and completely covers the surface of the water for five minutes, report ZERO HARDNESS.
7. If the lather does NOT persist, add about 1/10 of a milliliter (several drops) of soap solution, stopper the bottle, shake it vigorously, lay it on its side, and start the stop watch. Repeat the procedure as often as necessary, until a lather is obtained which completely covers the surface of the water for five minutes.
8. Read the burette. (Take the reading at the BOTTOM of the meniscus.)

9. Subtract the lather factor from the burette reading, and multiply by the constant 0.20. This will give you the hardness of the sample in equivalents per million.

Let's assume, for example, that you are making a hardness test using a reagent soap solution with a lather factor of 0.30 ml. You add 0.30 ml of soap solution to your boiler water sample. If the lather persists for five minutes, you can report zero hardness. But suppose that the lather does not persist. You add 0.10 ml (1/10 ml) of soap solution, but even this does not make a lather which will persist for five minutes. You add another 0.10 ml, and perform the test again. This time the lather stays for five minutes. What is the hardness of the boiler water?

The burette reading will be 0.30 PLUS 0.10 PLUS 0.10, or a total of 0.50 ml. From this you must now SUBTRACT the lather factor. 0.50 ml MINUS 0.30 ml gives you 0.20 ml. Now multiply this number by the constant 0.20, and you have the measure of hardness of the boiler water: 0.04 epm.

Testing for Chloride

The chloride content of boiler water is found by the following procedure:

1. Use the 100-ml graduated cylinder to transfer 25 ml of the test water to one of the porcelain casseroles.
2. Add five drops of chloride indicator to the sample. The water will turn blue-violet or red, depending upon its alkalinity.
3. Using the nitric acid burette, add reagent nitric acid, one drop at a time, stirring continuously, until the violet or red color just disappears. (The water will probably be pale yellow.)
4. Add exactly 1 ml more of reagent nitric acid.
5. Fill the mercuric nitrate burette and let it drain down to zero. Drain some to fill the burette to the tip. Then refill the burette.

6. Add reagent mercuric nitrate from the burette, and stir continuously until a pale blue-violet color persists throughout the solution. Add the mercuric nitrate at a fairly rapid rate at first, but add it very slowly—drop by drop—as the end point is approached.
7. Read the burette. Take the reading from the BOTTOM of the meniscus. The burette is calibrated in milliliters. The reading is numerically the same as equivalents per million. Thus, a burette reading of 5.5 ml indicates a chloride concentration of 5.5 epm.

NAVY BOILER COMPOUND

Navy boiler compound is used in boiler water to maintain the proper alkaline condition; to eliminate hardness; to prevent corrosion; and to precipitate dissolved salts so they can be removed by surface and bottom blows.

Navy boiler compound is composed of disodium phosphate, sodium carbonate, and cornstarch. The disodium phosphate and the sodium carbonate combine with calcium and magnesium to form insoluble salts which precipitate as sludges. In addition, sodium carbonate maintains the alkalinity of the water and aids in the precipitation of scale-forming salts. The cornstarch in Navy boiler compound serves to increase the mobility of the sludges.

Calculating the Dosage

The amount of compound which must be added to a boiler to control the alkalinity and hardness of the boiler water depends upon two things: (1) the water capacity of the boiler at steaming level, and (2) the condition of the water, as ascertained by the alkalinity and hardness tests. When these two factors are known, the calculation of dosage may be made from the charts shown in figures 8–5 and 8–6.

Figure 8–5 shows the chart used for calculating boiler compound dosage for a steaming boiler, on the basis of the results of the alkalinity test. Place a straight edge across the

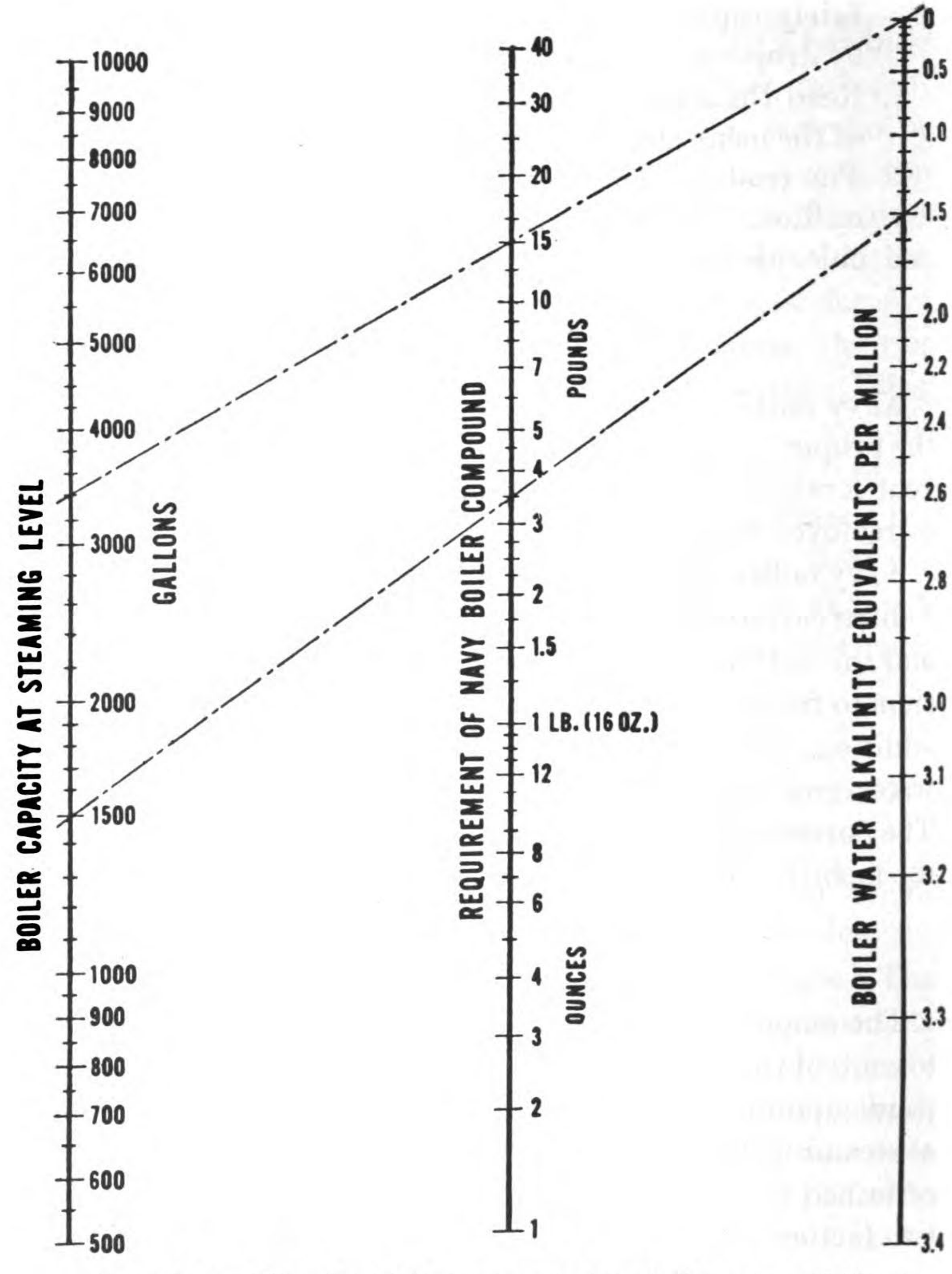


Figure 8–5.—Chart for calculating dosage from boiler water alkalinity.

chart from the point of alkalinity (right-hand scale) to the water capacity at steaming level (left-hand scale). The point where the line crosses the middle scale indicates the amount of compound which must be added in order to bring the alkalinity up to the upper alkalinity limit of 3.5 epm.

Figure 8–5 should also be used to determine boiler compound dosage when a boiler has been emptied and is being filled to steaming level with fresh feed water. In this case, place the straight edge across the chart from ZERO alkalinity to the water capacity at steaming level.

When a boiler is to remain idle for some time, it should be filled to the aircocks. The amount of boiler compound which must be added in order to maintain proper alkalinity may be determined in the following manner:

1. Take the DIFFERENCE between the water capacity of the boiler at steaming level and the water capacity of the boiler when filled to the aircocks. (This is the amount of additional fresh feed water which will be required to raise the water level to the aircocks.)
2. Lay a straight edge across the chart, between the figure obtained in step 1 on the LEFT-HAND scale and ZERO alkalinity on the RIGHT-HAND scale. The reading on the middle scale will show the amount of compound to be added.

Figure 8–6 shows the chart used for calculating the boiler compound dosage when the boiler water test shows that some hardness is present. The dosage is obtained from this chart by laying a straight edge across the chart from the point of hardness (epm) to the water capacity of the boiler. The point where the line crosses the middle scale indicates the amount of compound to be added to bring the boiler water to zero hardness.

An alkalinity test must ALWAYS be made again after boiler compound has been added. If the alkalinity test indicates more than 3.5 epm, the excess alkalinity must be removed by blowdown. If the boiler compound was added because of hardness, a new hardness test must be made as well.

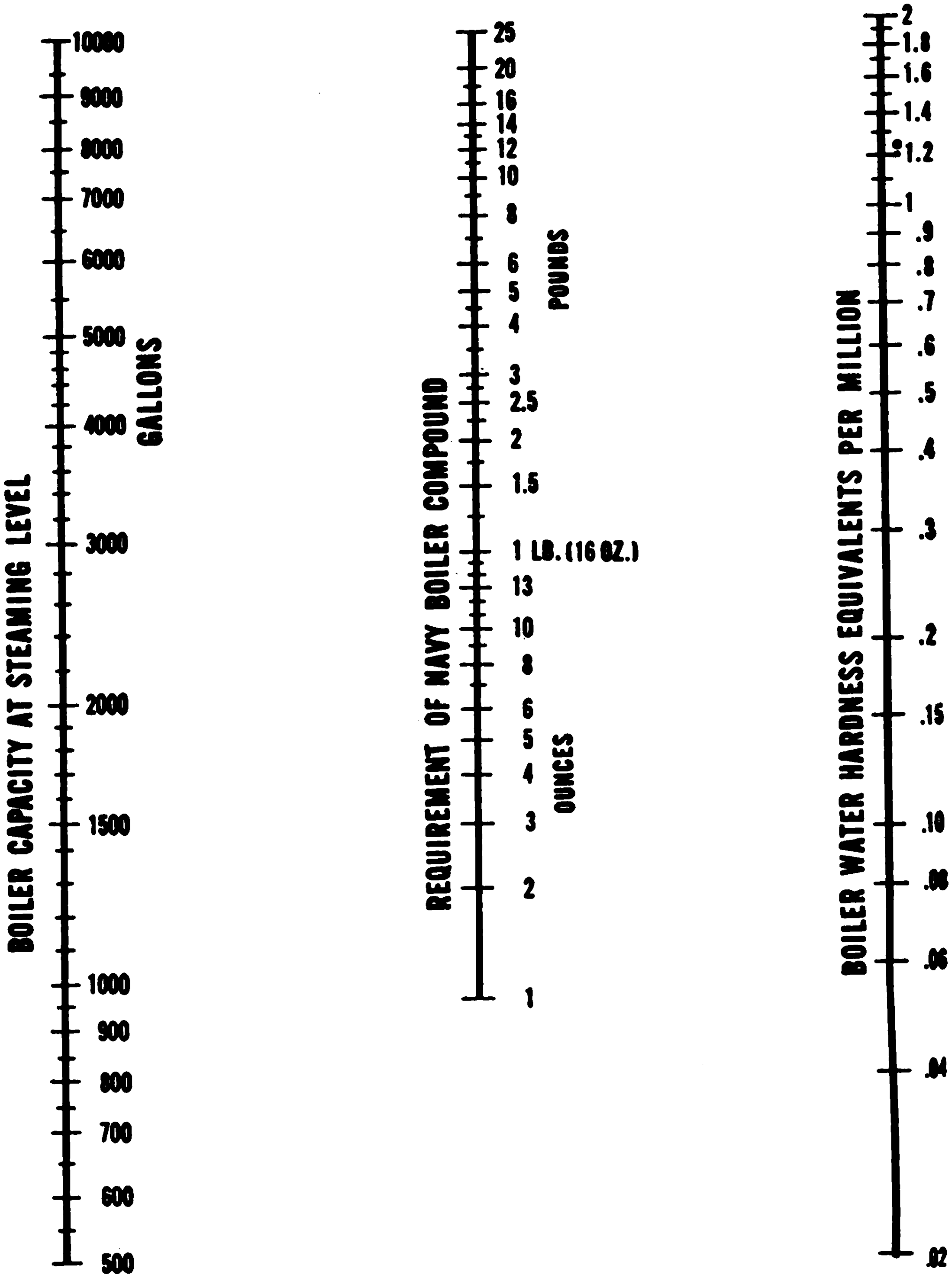


Figure 8–6.—Chart for calculating dosage from boiler water hardness.

Adding Boiler Compound

Navy boiler compound should be dissolved in hot (preferably boiling) water. It should be mixed in the ratio of about 1 pound of compound to 5 quarts of water. Vigorous stirring is required in order to be sure that all the compound is dissolved.

As a rule, the emergency feed pump is used to pump the boiler compound solution to the boiler. When adding compound, it is important to run the emergency feed pump long enough so that all compound will be washed out of the feed line. Boiler compound may be added in a single dose, or in several doses.

SURFACE AND BOTTOM BLOWS

Chemical treatment with Navy boiler compound does not reduce the need for blowdown. Although chemical treatment is necessary, it has the adverse effect of increasing the concentration of impurities in the boiler water. Therefore, boiler water treatment must include (1) proper use of Navy boiler compound, and (2) judicious use of surface and bottom blows.

The principal purpose of blowdown is to prevent the boiler water from becoming too concentrated with any dissolved or suspended substances. A blowdown simply draws off some of the water, which is then replaced by pure water. Total concentration is reduced by this dilution.

The surface blow is more effective than the bottom blow in removing floating materials such as oil, and dissolved salts which circulate with the boiler water. It is reasonably effective in controlling sludges.

The bottom blow must be used to remove the heavy solids which settle in the lower drums and tube bends. A series of short blows is more effective than one long blow. The bottom blow is most effective when given about two hours after the boiler has been secured. By this time the sludges will have settled, but there will still be sufficient boiler pressure to produce a vigorous flow. In any case, water wall and

water screen headers must not be blown while the boiler is lighted off, since this procedure would disrupt the circulation in the tubes.

Blowdown may also be used to reduce the chloride concentration. If the chloride concentration is very high, however, the most economical procedure is to secure the boiler, drain off the water, and refill the boiler with fresh water.

QUIZ

1. What three characteristics of boiler water must be carefully controlled?
2. What is the standard unit for reporting all boiler water analyses?
3. What hardness is allowable in boiler water?
4. What are the alkalinity limits for boiler water?
5. What is the maximum allowable chloride concentration for express boilers?
6. Why is it particularly important to keep all boiler water testing equipment clean?
7. To what temperature should boiler water be cooled before it is tested for alkalinity, hardness, or chloride?
8. What alkalinity test is used for steaming boilers and for idle boilers which have been steamed?
9. What is the methyl-purple test used for?
10. When making the phenolphthalein test, you get a burette reading of 3.4 ml. What is the alkalinity of the boiler water, in equivalents per million?
11. What term is used to describe the amount of a given soap solution which is required to produce a lather in pure water?
12. Suppose that you make a hardness test, using a soap solution with a lather factor of 0.35. If you have to add 0.30 ml MORE than the lather factor before obtaining a lather which will persist for five minutes, what is the hardness of the boiler water?
13. When reading a burette, where should you take the reading?
14. Calculate the amount of Navy boiler compound which should be added to the boiler water if: (1) the boiler capacity at steaming level is 2000 gallons, and (2) an analysis shows the alkalinity to be 2.0 epm.
15. If you add the amount of Navy boiler compound which you determined in the previous question, what should the alkalinity of the boiler water be?

CHAPTER 9

FEED WATER SYSTEMS

Broadly speaking, a feed water system includes all apparatus and piping used to collect steam and to condense it so that the water may be fed to the boilers. However, a feed system should properly be considered in three parts: (1) the condensate system, (2) the boiler feed system, and (3) the fresh water drain system.

CONDENSATE SYSTEM

The condensate system condenses exhaust steam and delivers the condensate to the boiler feed system. The condensate system consists of the main and auxiliary condensers and a pump or a combination of pumps.

The CONDENSERS (main and auxiliary) recover feed water by condensing exhaust steam from the propulsion turbines, the generator turbines, and various auxiliary machinery units.

In modern feed water systems, a centifugal CONDENSATE PUMP is used to pump the condensate to the boiler feed system; and a two-stage AIR EJECTOR is used to remove air from the condenser.

BOILER FEED SYSTEM

The boiler feed system delivers the condensate as feed water to the boilers. In addition, the boiler feed system provides some means of heating the water and, in modern systems, a device for removing air from the condensate.

The fresh water drain system recovers feed water from steam which loses heat and condenses into water without doing any useful work, and from steam which condenses into water after giving up its heat in various heat-exchanger equipment—fuel oil heaters, distilling units, water heaters, ventilation heaters, and others. The system of piping which carries this water to the feed system, and also the water itself, are referred to as DRAINS.

There are five types of fresh-water drains on naval vessels: (1) high-pressure drains; (2) low-pressure drains; (3) gravity drains; (4) contaminated drains; and (5) special drains. Every drain line (except for gravity drains) is fitted with an impulse, thermostatic, or bucket-type steam trap which prevents steam from passing into the drain system.

HIGH-PRESSURE DRAINS generally include drains from superheater headers, throttle valves, main and auxiliary steam lines, steam separators, and whistles and sirens. In modern feed systems, the high-pressure drains are led into the deaerating feed tank so that their heat may be utilized.

LOW-PRESSURE DRAINS are those coming from (or connected with) the auxiliary exhaust piping. In modern feed systems, the low-pressure drains go into a low-pressure drain tank (sometimes called a fresh water drain collecting tank), from which the water is automatically drawn into the main or auxiliary condenser through a float-type regulating valve.

GRAVITY DRAINS are provided for the rapid draining of large quantities of water, such as may be present during the warming up of a machinery unit or a steam line. Gravity drains are atmospheric-pressure drains. They include OPEN-FUNNEL DRAINS or SIGHT-FLOW DRAINS. Open-funnel drains are installed at-the lowest points on machinery and piping. These drains, and other gravity drains such as the drains from the air ejector after condenser and the vent condenser, go to the fresh water drain collecting tank.

CONTAMINATED DRAINS are those which serve heating units

or other systems in which there is a possibility of oil leakage into the steam side. Contaminated drains include drains from heating coils in fuel oil service, storage, and settling tanks; from lubricating oil heaters; and from fuel oil heaters. Contaminated drains pass through a drain inspection tank before entering the feed system. The inspection tank has a glass strip along the side, through which the water may be seen. If the water is not contaminated, it goes to the feed system; if it is contaminated with oil, the drain inspection tank discharge must be shifted to the bilges or, if practicable, to the contaminated drain tank.

Special drains include drains from the heating system, from the galley and scullery, and from hot water heaters. These drains go to a heating system drain tank, which is usually provided with a float-actuated drain pump. The heating system drain tank is usually fitted with an air ejector which maintains the tank under a partial vacuum.

Under normal operating conditions, the water from the heating system drain tank enters the condensate discharge line of the vent condenser, just before the condensate is sprayed out into the deaerating feed tank. However, provision is made for the heating system drains to be discharged to the low-pressure drain collecting tank, or directly to the reserve feed transfer main and so to the reserve feed tanks. If the heating system drains are discharged to the reserve feed tanks, extra makeup feed must be taken on to compensate for the loss of these drains from the system.

DEVELOPMENT OF FEED WATER SYSTEMS

Four main types of feed water systems have been used on naval vessels. In order of their development, they are:

1. The open feed system
2. The semi-closed feed system
3. The vacuum-closed feed system
4. The pressure-closed feed system.

As operating pressures and temperatures have increased, the removal of oxygen in feed water has become increasingly

important. Each new type of feed system represents an improvement over the one before, primarily in terms of efficiency in the elimination of dissolved or suspended oxygen from the feed water.

Practically all modern naval vessels use the pressure-closed system. However, you should have some knowledge of the earlier systems, as well, since they are still found on some naval auxiliary vessels. Furthermore, an understanding of the earlier systems will help you to understand the reasons for the development of the modern pressure-closed system.

In the following discussion of these various types of feed systems, we will omit description of the auxiliary condenser and its associated equipment. The auxiliary condenser is very similar to the main condenser, but has, of course, a smaller capacity.

The OPEN FEED SYSTEM, shown in figure 9–1, is suitable for use only when boiler pressures are 300 psi or below. In this system, a reciprocating WET AIR PUMP discharges a mixture of condensate and air from the condenser to the FEED AND FILTER TANK. The upper part of the feed and filter tank contains filtering material which removes dirt and oil from the passing condensate. (The filter was necessary at this stage of development, since most machinery was of the reciprocating type, requiring oil lubrication; thus it was inevitable that some oil would find its way into the condensate.) The lower part of the feed and filter tank is essentially a reservoir for the condensate. A reciprocating MAIN FEED PUMP pumps the condensate through a FEED HEATER, where the water is heated by exhaust steam, and then into the boiler.

Drains from the feed heater and other miscellaneous drains may be led either to the condenser or to the feed and filter tank. The water level in the system is controlled by a makeup feed line from the RESERVE FEED TANK to the condenser, and by the OVERFLOW LINE from the feed and filter tank to the reserve feed tank. A makeup feed pump is provided for emergency filling of the feed and filter tank from the reserve feed tank.

In the open feed system just described, the condensate is

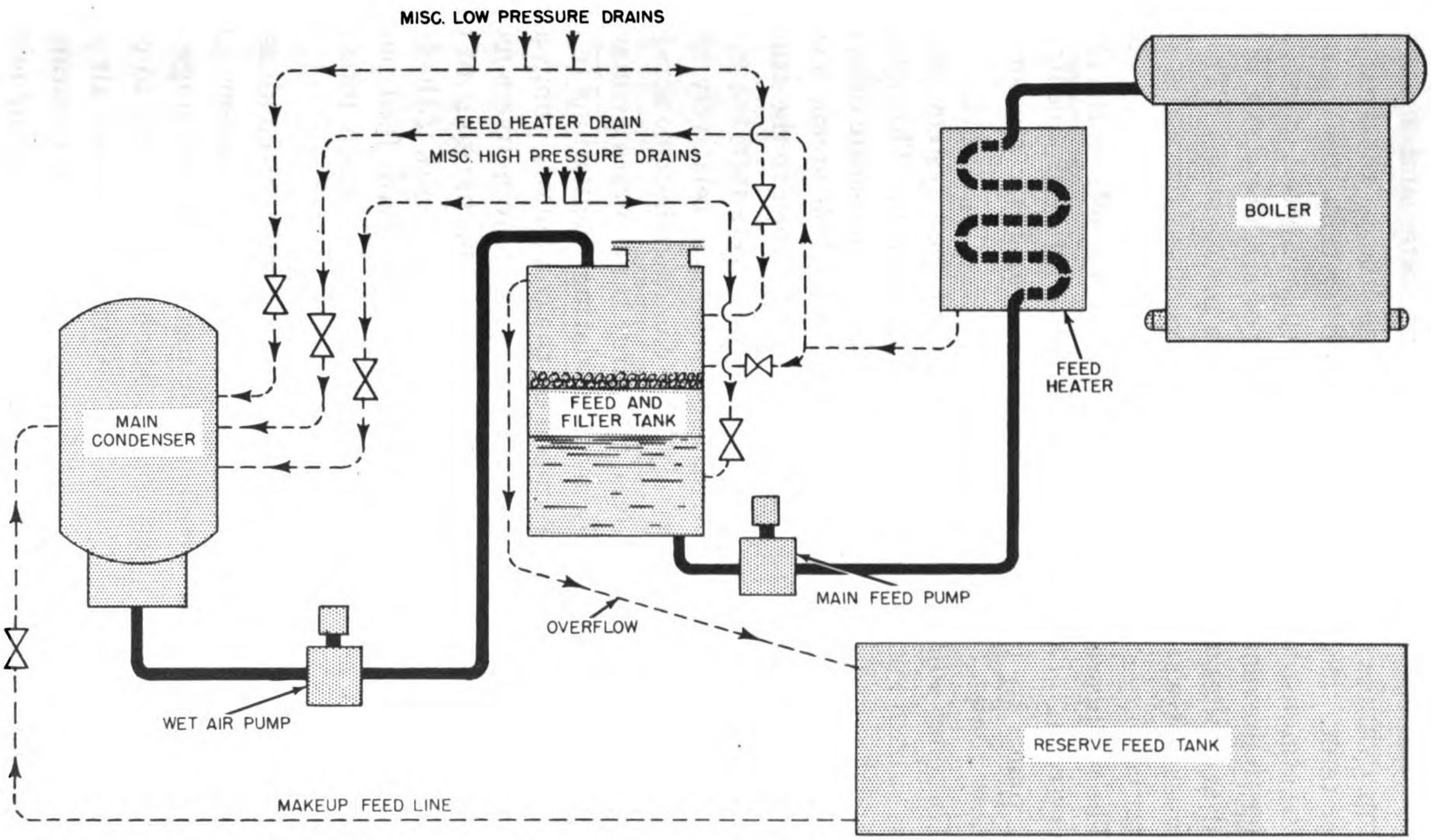


Figure 9–1.—Open feed system.

subject to a considerable amount of aeration. First of all, the reciprocating wet air pump mixes water and air in the pump cylinders and in the discharge line to the feed and filter tank. Secondly, the feed and filter tank itself is open to the atmonsphere, and the water is thus exposed to air. In order to prevent excessive absorption of air, the water in the feed and filter tank is kept as hot as practicable. (This is because hot water cannot hold as much dissolved air as cold water can.)

The reciprocating wet air pump was used only in the earliest systems. Later open feed systems employed a centrifugal pump to remove the condensate, and air ejectors to remove the air, from the condenser.

The next step in the development of feed systems is the SEMI-CLOSED FEED SYSTEM, shown in figure 9–2. This system is called SEMI-CLOSED because most of the condensate does not come in contact with the atmosphere. The SURGE TANK, which replaces the feed and filter tank, is open to the atmosphere; but most of the condensate never gets into the surge tank. Thus, in this system, condensate has relatively little exposure to air, and relatively little chance to become aerated.

In the semi-closed system, the surge tank serves primarily to stabilize the system by accommodating fluctuations in the amount of water being pumped by the condensate pump and the main feed pump. If the condensate pump delivers more condensate than the main feed pump is discharging to the boiler, the excess water enters the surge tank; and, if the condensate pump supplies less water than the main feed pump requires, the necessary amount of water is drawn into the system from the surge tank.

In the semi-closed feed system, a centrifugal condensate pump is used to remove condensate from the condenser. Air is removed from the condenser by means of a two-stage AIR EJECTOR, and an AIR EJECTOR CONDENSER is provided to condense the steam used by the air ejectors. Since the air and the condensate are removed from the condenser separately, rather than together, the condensate does not become mixed with air.

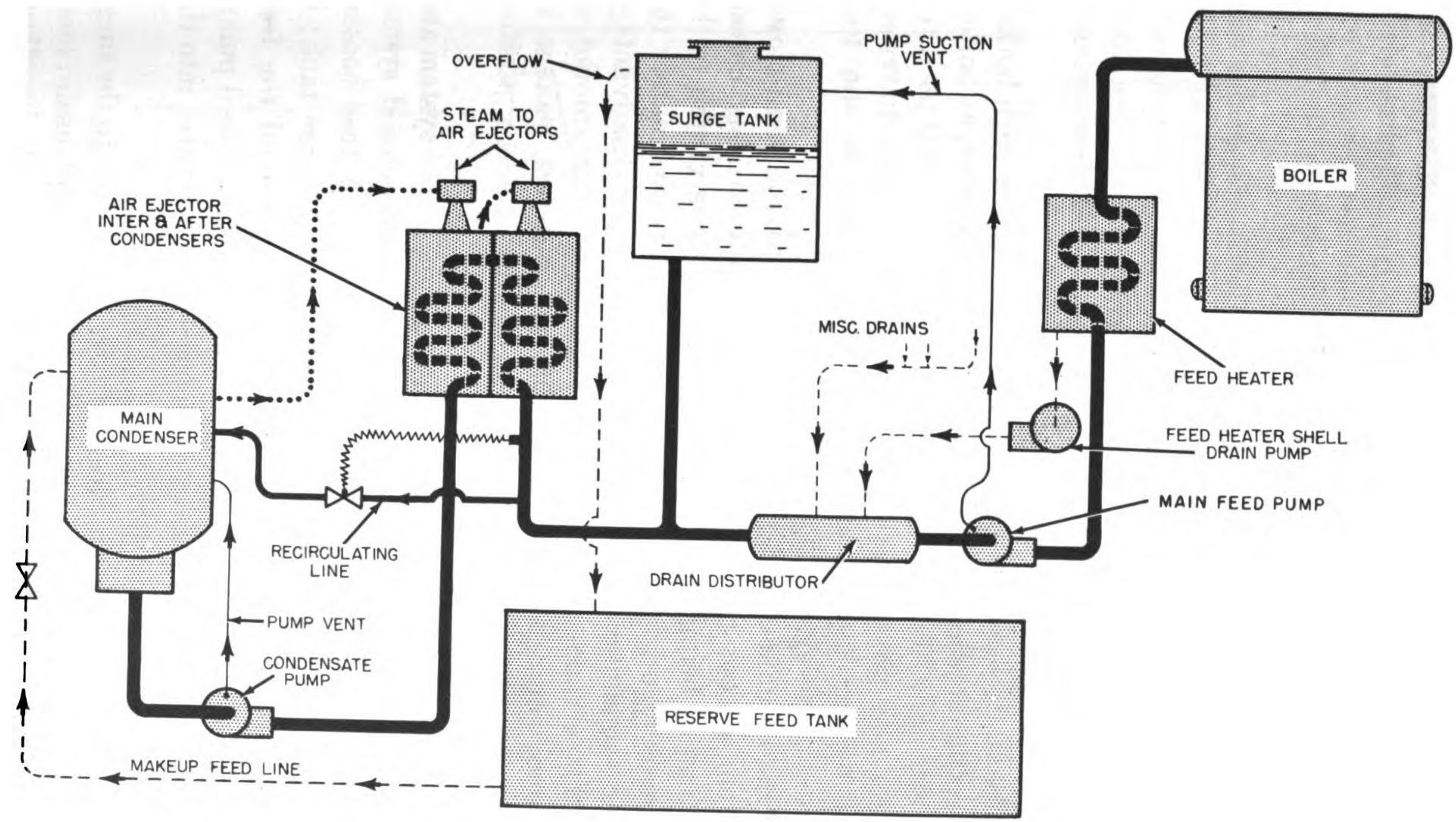


Figure 9–2.—Semi-closed feed system.

In the semi-closed feed system, a recirculating line is installed between the air ejector condenser and the main condenser. A thermostatically controlled valve in the line opens when the water leaving the air ejector condenser becomes too hot, thus allowing the water to flow back into the main condenser.

In figure 9–2 you will notice that the feed heater drains and the miscellaneous drains go into a DRAIN DISTRIBUTOR, and mix with the condensate in the main feed line. The disadvantage in this arrangement is that the drains are not deaerated before going to the boiler. Later semi-closed feed systems were modified to overcome this difficulty.

The semi-closed feed system is suitable for use with boilers operating at pressures of 300 to 400 psi. However, as boilers were designed for even higher pressures (400 to 600 psi), the VACUUM-CLOSED FEED SYSTEM was developed in order to reduce still further the amount of dissolved oxygen in the feed water. This system is shown in figure 9–3.

The vacuum-closed system is similar to the semi-closed system, except that the surge tank is now entirely closed. Instead of being open to the atmosphere, it is vented to the condenser and is thus maintained under approximately the same vacuum as the condenser. The primary disadvantage of this arrangement is that it requires a large amount of vacuum piping. (It is more difficult to detect leakage in vacuum piping than in piping which is under a positive pressure.)

A further difference between the vacuum-closed system and the semi-closed system is that in the vacuum-closed system all condensate goes through the surge tank. A feed booster pump takes suction from the bottom of the surge tank; it discharges through the air ejector condenser and the feed heater, and provides a positive head for the main feed pump. The main feed pump then discharges the feed water into the economizer of the boiler.

High-pressure drains are normally discharged to the surge tank, where their heat is utilized to boil the condensate; however, they may be discharged to the fresh water drain collect-

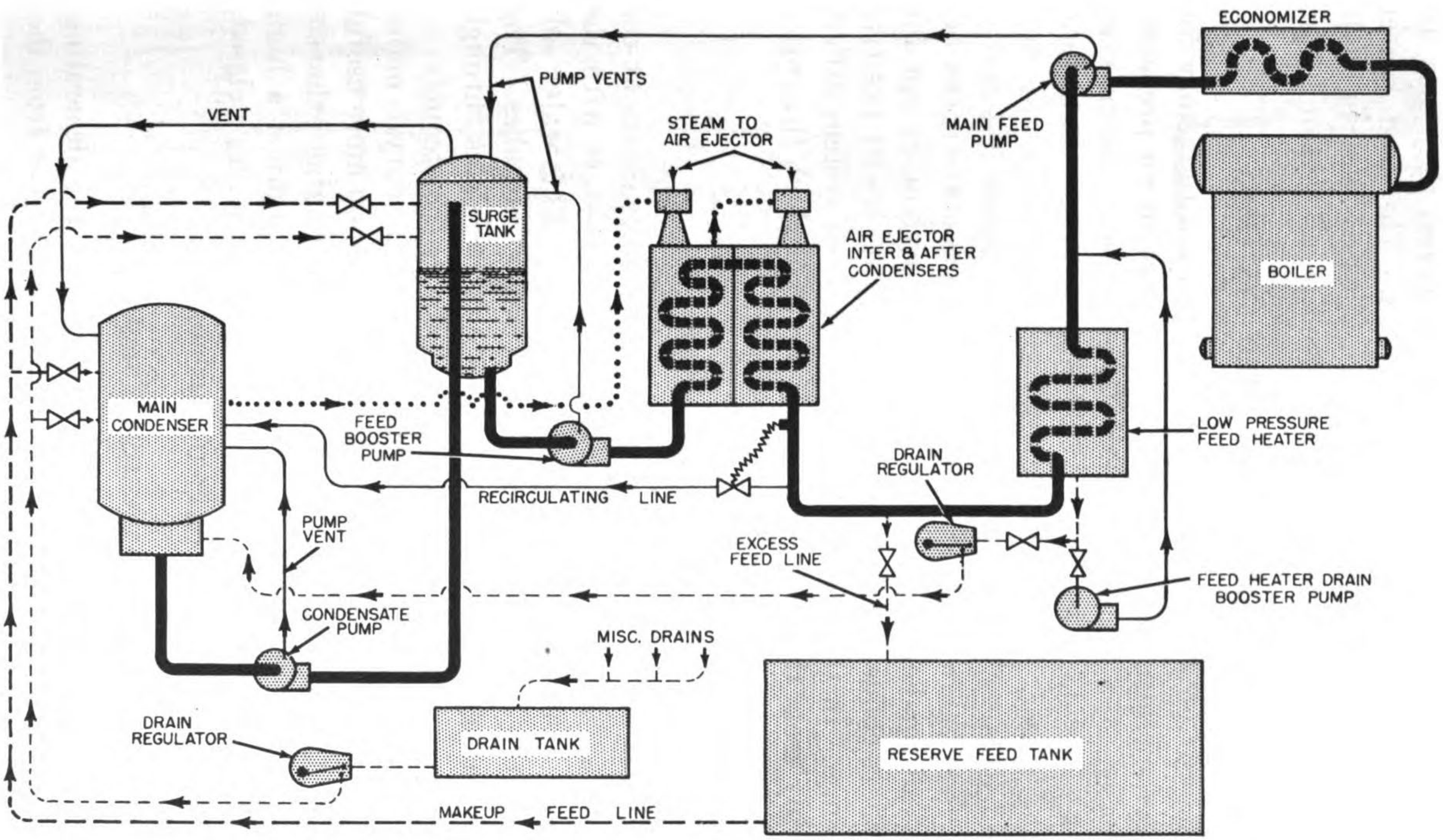


Figure 9–3.—Vacuum-closed feed system.

ing tank. Low-pressure drains are collected in the drain tank and normally go to the condenser; however, they may be discharged directly to the surge tank. The feed heater drains normally go to the condenser, but provision is made for them to be pumped to the main feed pump suction.

PRESSURE-CLOSED FEED SYSTEM

The vacuum-closed feed system was fairly satisfactory for boilers operating at 400 to 600 psi. As operating pressures increased still further, however, the PRESSURE-CLOSED FEED SYSTEM was developed to provide more complete deaeration of the water. A pressure-closed system, similar to that found on most naval vessels, is shown in figure 9–4 and is described below. The system is called PRESSURE-CLOSED because all condensate lines throughout the system, except for the short condensate pump suction lines, are under positive pressure. In this respect the pressure-closed system differs sharply from the vacuum-closed system, in which the entire condensate system is under high vacuum.

Main Condenser

Exhaust steam from the propulsion turbines enters at the top of the condenser and, upon coming in contact with the cold condenser tubes, condenses into water. This water collects at the bottom of the condenser, below the tubes. The tubes are kept cold by sea water, which circulates through them and carries away the heat given up by the steam.

A vacuum of approximately 29 inches of mercury is maintained in the main condenser. An engine can do more useful work with a given amount of steam if the engine exhausts to a low-pressure space than if it exhausts against a high pressure; and the condenser under vacuum provides a closed, low-pressure place for the engine exhaust.

Condensate Pump

Water is pumped from the condenser to the deaerating tank by the condensate pump. As the water goes from the condenser to the deaerating tank, it passes successively

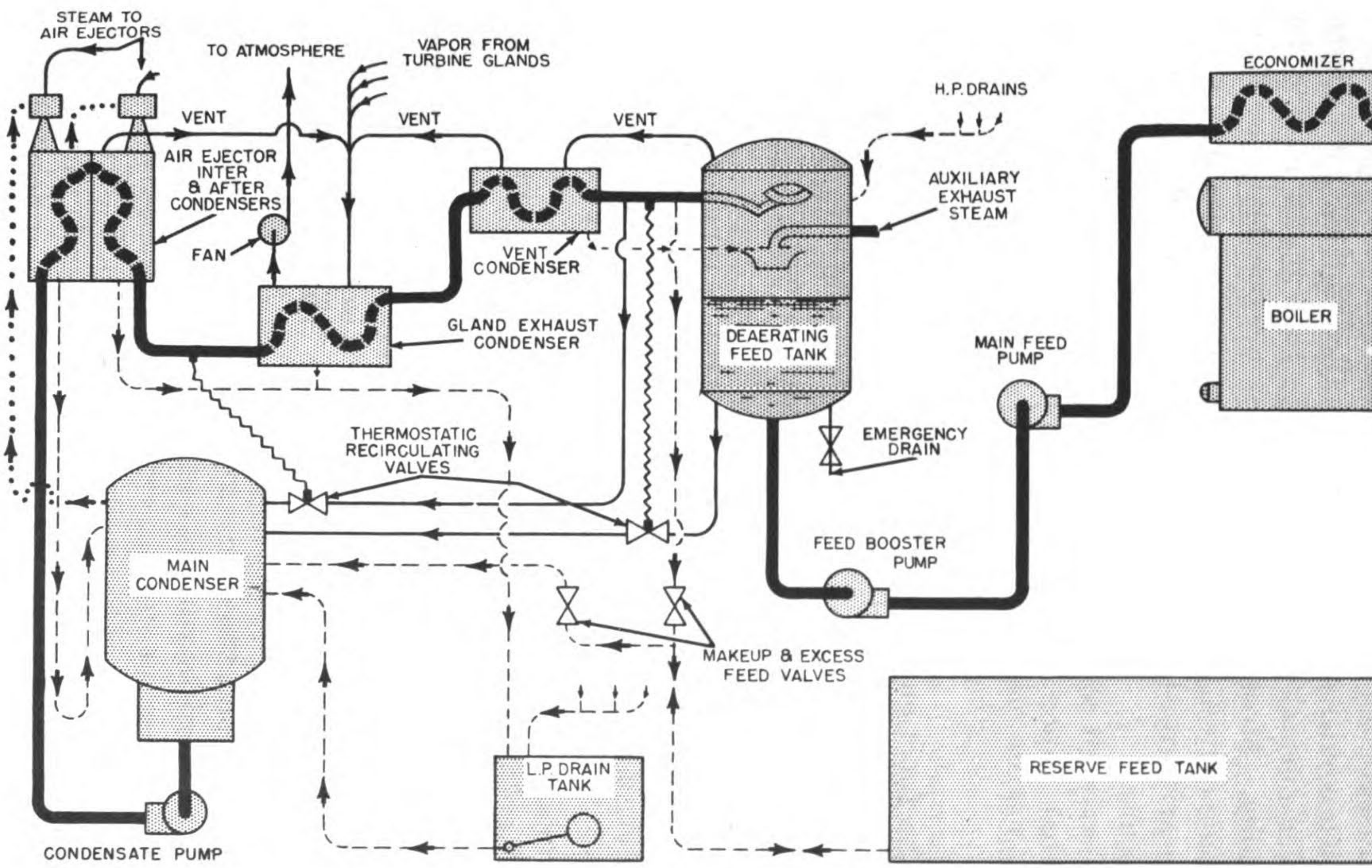


Figure 9–4.—Pressure-closed feed system.

through the tubes of the air ejector condenser, the gland exhaust condenser, and the vent condenser.

Two condensate pumps are installed for each condenser. Under normal steaming conditions, one pump is used for standby. Most condensate pumps are vertical, two-stage, turbine-driven, centrifugal pumps. Condensate pumps run at nearly constant speed and deliver water at a constant pressure.

Nearly all condensate pumps are vented to the condenser, so that vapor will not be trapped in the pump suction chamber.

Air Ejector Condenser

The function of an air ejector is to remove air and other gases from the condenser. An air ejector is a type of jet pump, containing no moving parts. The flow through the air ejector is maintained by a jet of high-velocity steam passing through a nozzle.

The air ejector assembly used to remove air from the main condenser consists of a first-stage air ejector, an inter condenser, a second-stage air ejector, and an after condenser. The entire assembly is usually referred to as an AIR EJECTOR CONDENSER.

The first-stage air ejector takes suction on the main condenser and discharges the steam-air mixture to the inter condenser, where the steam content of the mixture is condensed. The resulting condensate drops to the bottom of the inter condenser shell, and from there drains to the main condenser through a **U**-shaped loop seal line. The air passes to the second-stage air ejector suction.

In the second-stage air ejector, another jet of steam is used. The steam-air mixture is now discharged into the after condenser, where the steam is condensed and the air is vented to the atmosphere. (Normally, the air is vented to the atmosphere by way of the gland exhaust condenser; however, in some installations it is vented directly to the atmosphere from the air ejector after condenser.) The second-stage air ejector actually does most of the work in maintaining the vacuum on the main condenser.

Condensate from the main condenser is used as the cooling water in the air ejector inter and after condensers. It is important to note that this is the ONLY reason why condensate passes through the air ejector condenser. The air ejectors remove air only from the condenser, not from the condensate.

The inter condenser is under vacuum of about 26 inches of mercury. The after condenser is at approximately atmospheric pressure.

Gland Exhaust Condenser

The gland exhaust condenser receives a steam-air mixture from the propulsion turbine glands. The steam is condensed and returned to the feed system, and the air is discharged to the atmosphere by means of an exhaust fan. As mentioned before, air from the air ejector after condenser is normally vented through the gland exhaust condenser.

Condensate is used as the cooling water in the gland exhaust condenser, as it is in the air ejector inter and after condensers. The temperature of the condensate is increased, of course, in the air ejector condenser and again in the gland exhaust condenser.

Vent Condenser

The vent condenser is actually a part of the deaerating feed tank. However, it is mentioned here because it is the next unit in the system after the gland exhaust condenser. In the vent condenser, condensate once against serves to cool and condense steam from a steam-air mixture; and in the process the temperature of the condensate is again increased. The vent condenser receives steam and air from the deaerating feed tank. The steam condenses into water which is fed back to the deaerating feed tank. The air goes to the gland exhaust condenser and is vented to the atmosphere. The action which takes place in the vent condenser is described more fully in the discussion of the deaerating feed tank.

Thermostatic Recirculating Valves

Two thermostatically-controlled recirculating valves provide for condensate recirculation, when this is required in

order to maintain an adequate supply of cooling water to the air ejector condenser, the gland exhaust condenser, and the vent condenser. It is desirable, of course, to return the condensate to the deaerating feed tank at a high temperature. If the condensate is too hot, however, the air ejector condenser and the other heat exchangers through which the condensate passes will not be sufficiently cooled, and therefore will not operate properly.

The control element for the first recirculating valve is installed in the condensate discharge line from the air ejector after condenser (or, in some cases, in the discharge water chest of the after condenser). When the condensate at this point becomes too hot, the control element opens the recirculating valve. Condensate is thus drawn back to the main condenser, where it is cooled. It is then recirculated through the air ejector condenser.

The control element for the second recirculating valve is installed in the vent condenser condensate discharge line. When the condensate at this point becomes too hot, the control element actuates a recirculating valve which allows water from the deaerating feed tank to flow back to the main condenser.

Makeup and Excess Feed Valves

Makeup feed water from reserve feed tanks is brought into the system when necessary. A manually operated valve is provided for this purpose. All makeup feed is brought in through the condenser.

Another manually operated valve allows excess feed to be discharged from the condensate line (either before or after the vent condenser) to the reserve feed tanks.

Deaerating Feed Tank

The deaerating feed tank (fig. 9–5) serves to heat, deaerate, and store the feed water. The water is heated in the deaerating tank by direct contact with auxiliary exhaust steam. The auxiliary exhaust steam pressure is approximately 2 psi higher than the pressure in the deaerating tank. The de-

aerating tank is usually designed to operate at a pressure of approximately 10 to 15 psi gage, and to heat the water to between 240° and 250° F. The water is kept just under its boiling point at the operating pressure, so that it will not flash into steam.

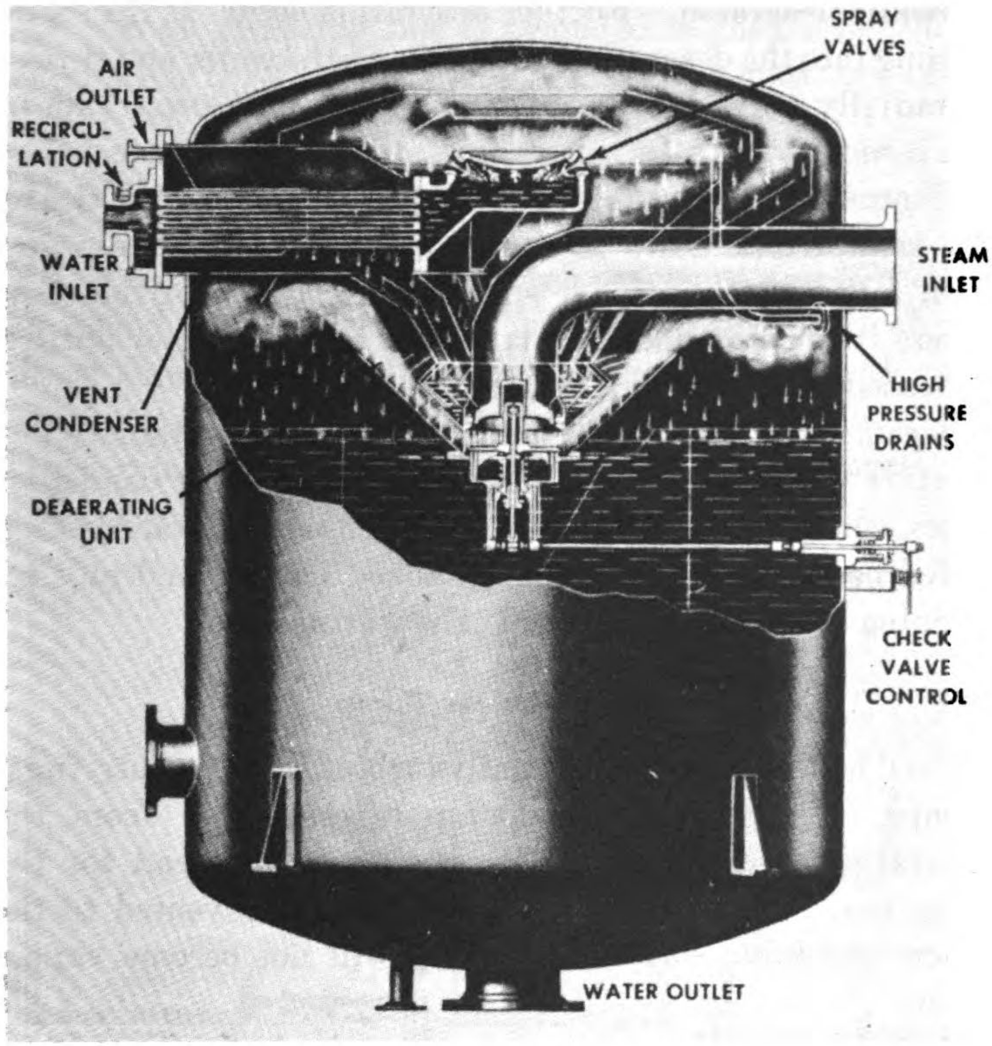


Figure 9–5.—Deaerating feed tank.

Condensate enters the deaerating feed tank through the tubes of the vent condenser; it is forced out through a number of spray valves in the spray head, and is discharged in a fine spray throughout the steam-filled upper section of the deaerating tank. The tiny droplets of water are heated and

scrubbed by the relatively air-free steam, so that practically all of the dissolved air is released. The drops of water fall through the steam-filled atmosphere and are collected in a cone-shaped baffle which leads them, through a central port, to the deaerating unit.

By this time, the water has been partially heated and partially deaerated. Further deaeration occurs as the steam coming into the deaerating unit picks up the water and throws it radially outward and upward against the lower side of the conical baffle. In this process, the water and steam are so thoroughly mixed that the water is heated to practically the same temperature as the steam. The deaerated water then falls into the storage space at the bottom of the tank, where it remains under a blanket of air-free steam until it is needed for the boilers.

Steam sweeps the air from the deaerating feed tank. The mixture of steam and air travels across the vent condenser tubes, where some of the steam is condensed into water which is fed back into the deaerating tank. The air and any remaining steam go to the gland exhaust condenser.

Feed Booster Pump

Feed booster pumps are usually turbine-driven, centrifugal pumps. The feed booster pump takes suction from the deaerating feed tank, and provides a positive head for the main feed pump. The feed booster pump is vented to the deaerating tank, so that the pump will not become vapor-bound.

A line called the STARTING-UP LINE leads from the feed booster pump discharge piping to a point in the main condensate piping beyond the air ejector condenser. When the deaerating feed tank is being warmed up, this line is used to recirculate heated water from the bottom of the deaerating tank back through the vent condenser. This recirculation is generally continued for about 10 minutes, in order to ensure complete deaeration of the water.

Main Feed Pump

The main feed pump was described in the chapter on pumps. As you will recall, this pump is a high-speed, multistage, horizontal, turbine-driven, centrifugal pump. The main feed pump operates at variable speed, the speed being adjusted automatically by the constant-pressure pump governor. A recirculating line is provided to ensure continuous circulation through the pump. This line must ALWAYS be open when the main feed pump is in operation.

TRANSFERRING FEED WATER

The feed water system has been described and illustrated as though it were a single plant. However, practically all naval ships have more than one of these plants, with cross-connecting lines and valves arranged so that the plants may be operated either independently (split-plant) or together as a single plant (cross-connected). When warming up or se-

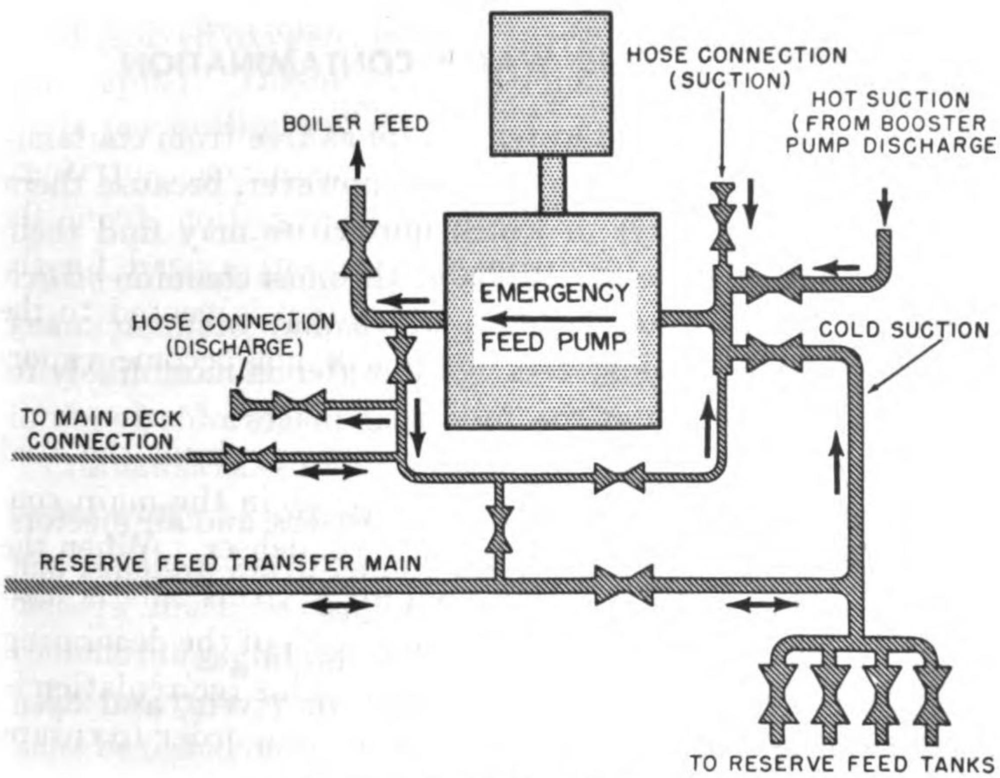


Figure 9–6.—Emergency feed pump connections.

curing one plant, it is frequently necessary to transfer feed water from one plant to another. For example, feed water should be transferred between plants so that one plant will not be taking on makeup feed while the other is discharging excess feed.

Since the reserve feed tanks are normally filled by discharge from the distilling plant, it is seldom necessary to transfer feed water from one tank to another. However, the emergency feed pump can be used to transfer feed water from any tank in one group of reserve feed tanks to any tank in another group. The piping, valves, and connections which make this possible are shown in figure 9–6. The piping arrangement varies, of course, from one installation to another; but you can figure out the general principles involved by studying this diagram. In particular, note that THIS emergency feed pump cannot transfer water from the reserve feed transfer main to the reserve feed tanks shown in the diagram; if water is to be transferred into these tanks, it must be pumped by the emergency feed pump in the other plant.

SOURCES OF FEED WATER CONTAMINATION

It is essential that feed water be kept as free from contamination as possible. This is not easy, however, because there are a great many ways in which impurities may find their way into the feed system. Probably the most common source of trouble is salt water leakage, which may occur at many different points in the system. Salt water is most likely to enter the feed system at the following places:

1. Main and auxiliary condensers
2. Distilling plant evaporators, condensers, and air ejectors
3. Drain collecting tanks, open funnel drain systems, and drain lines which run through bilges
4. Feed suction lines which run through bilges
5. Reserve feed tanks (leaky seams or rivets, and open sounding tubes)
6. Bottom blow valves (on idle boilers only).

Other types of contamination may occur when oil leaks into the steam side of fuel oil heaters or oil tank heating coils, when lube oil leaks from turbine bearings, and when air leaks into the parts of the system which are under vacuum. If there is evidence of any type of feed water contamination, every effort should be made to find the source and to correct the condition.

FEED WATER TESTS

At regular intervals, feed water must be tested for chloride and for hardness. In addition, tests must be made to determine the dissolved oxygen content of the water on the discharge side of each operating deaerating feed tank. Some vessels are supplied with the equipment for making dissolved oxygen tests; vessels not so supplied must have the tests made at a naval shipyard or tender. Routine alkalinity tests are not made on feed water.

The units for reporting the results of water analyses were discussed in the chapter on boiler water treatment. It is important to remember that all water tests EXCEPT the test for dissolved oxygen must be reported in equivalents per million (epm). Dissolved oxygen must always be reported in parts per million (ppm).

Chloride

The chloride content of feed water should, of course, be as low as possible, and must never be allowed to exceed the specified limits. The frequency of testing and the allowable limits of chloride content are:

CONDENSATE.—The condensate in main condensers must be tested every 15 minutes while under way, and every 30 minutes while standing by. The condensate in auxiliary condensers must be tested every 30 minutes. The chloride content must not exceed 0.1 epm.

DEAERATING FEED TANKS (OR SURGE TANKS).—The water must be tested once during each watch. The chloride content should not exceed 0.15 epm, and must not exceed 0.5 epm.

RESERVE FEED TANKS.—The water must be tested once a week, and, in addition, just before the water is used. The chloride content must not exceed 0.5 epm.

The chloride content of feed water may be determined either by the chemical chloride test or with the electrical salinity indicator. Electrical salinity indicator readings should be checked frequently by the chemical test.

When making a chemical test for chloride content in feed water, use the same procedure as in testing boiler water. However, the feed water sample must be 100 ml in size, rather than 25 ml; and the burette reading must, accordingly, be DIVIDED BY 4. Thus, on a BOILER WATER TEST, a burette reading of 2.0 would indicate a chloride concentration of 2 epm; but on a FEED WATER TEST, a burette reading of 2.0 would indicate a chloride concentration of 0.5 epm—that is, 2.0 DIVIDED BY 4.

Electrical salinity indicators are installed in almost all naval vessels. Since the electrical resistance of a solution varies according to the amount of ionized salts in solution, it is possible to measure salinity by measuring the electrical resistance. Resistance varies also with the temperature of the solution, so a temperature-compensation device must be set at a value corresponding to the temperature of the solution.

When reading the dial of an electrical salinity indicator, BE SURE THAT YOU KNOW WHAT YOU ARE READING! Some salinity indicators are still calibrated in a measuring unit called GRAINS OF SEA SALT PER GALLON. This unit is no longer used for reporting water analyses, so any reading taken in this unit must be converted to equivalents per million. Multiply the grains per gallon (meter reading) by 0.261 to get the chloride epm. For example, a meter reading of 0.60 grains of sea salt per gallon is equal to 0.60 multiplied by 0.261, or 0.156 epm chloride.

The calibration of an electrical salinity indicator should be checked by the following procedure:

1. Be sure the power is turned on to the indicator.
2. Set the temperature compensator at 110° F.

3. Push the test button, and hold it down until the reading is taken.
4. Read the indicator. The reading should be approximately 1 grain. If the salinity indicator does NOT give a reading of 1 grain, the instrument is not correctly calibrated and should be checked by an I. C. Electrician.

Hardness

Hardness tests must be made on deaerating feed tanks DAILY, on reserve feed tanks WEEKLY, and on all tanks just before the water is used as feed water. The hardness of makeup feed water must not exceed 0.5 epm.

The methods for determining and calculating the hardness of feed water are the same as those described for testing the hardness of boiler water.

Dissolved Oxygen

Dissolved oxygen tests should be made at least ONCE A WEEK, on vessels which are supplied with the necessary testing equipment. The tests are made on water discharged from OPERATING deaerating feed tanks; water from idle deaerating tanks is not tested. In addition, it may occasionally be necessary to make dissolved oxygen tests on water from other parts of the feed system, in order to locate sources of air leakage or oxygen contamination.

Deaerated feed water should not contain more than 0.02 ppm of dissolved oxygen.

The materials for making the dissolved oxygen test are found in a special cabinet, shown in figure 9–7. The principal items in this cabinet are:

1. Three 400-ml bottles, each with a side-arm aspirator and a 2-ml automatic-zero pipette. These bottles, which are labelled OXYGEN I, OXYGEN II, and OXYGEN III, are for the three fixing solutions used in the test for dissolved oxygen: Solution I, manganous sulphate; Solution II, alkaline iodide; Solution III, sulphuric acid

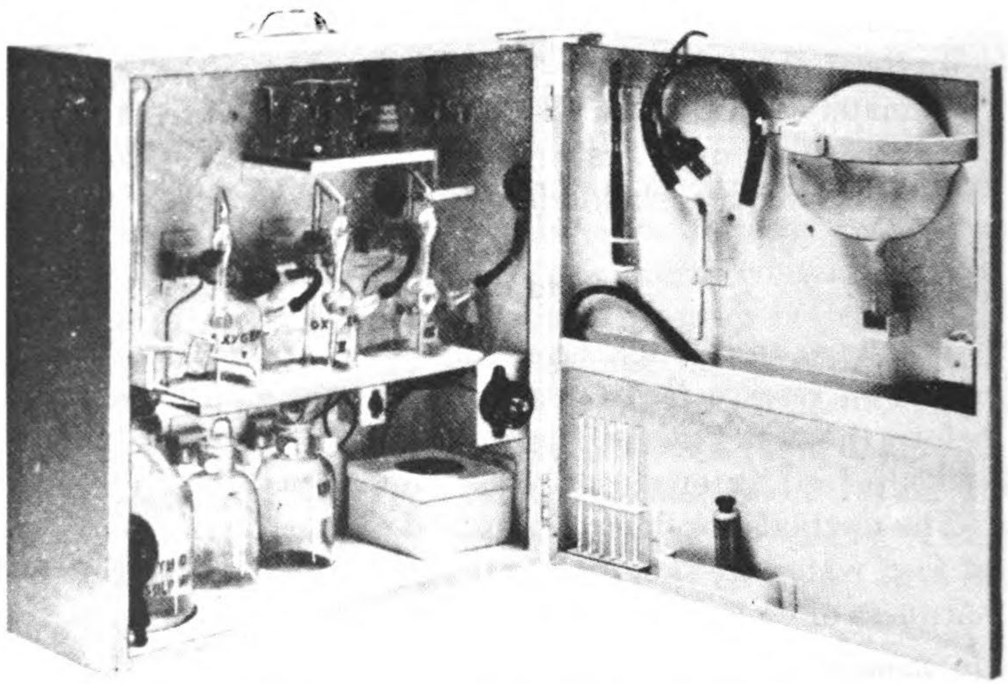


Figure 9–7.—Dissolved oxygen testing cabinet.

2. A 1-liter bottle with an aspirator and a 10-ml automatic-zero burette, for sodium thiosulphate solution
3. Two 300-ml sample bottles with cone-shaped, glass stoppers
4. A large casserole
5. A hot plate and a 150-ml beaker for use in preparing starch solution
6. A bottle of soluble starch
7. A dropping bottle for the starch solution
8. Glass tubing and rubber tubing, for use in obtaining water samples
9. A thermometer
10. A spatula (or a ¼-teaspoon measure)
11. A tube of lubricant for use ONLY on the stopcocks of the Oxygen I and Oxygen III pipettes.

Special precautions must be taken to maintain all dissolved oxygen testing equipment in satisfactory working condition. Some of the chemicals used in this test are very likely to clog

the pipette tips. All the equipment must be kept scrupulously clean; in particular, the pipettes must be carefully cleaned with distilled water immediately before and immediately after each use. The plug for the stopcock of the Oxygen II pipette must be kept in clean water in the beaker, when the testing kit is not in use.

The alkaline iodide solution and the sulphuric acid solution are very strong corrosive agents. Do NOT ALLOW THEM TO COME IN CONTACT WITH YOUR EYES, SKIN, OR CLOTHING. If these two solutions are accidentally mixed, a violent reaction will take place and the chemicals will spatter. If you do get these chemicals on your skin or clothing, use large quantities of fresh, clean water to wash them off IMMEDIATELY. If you get them in your eyes, get medical attention at once.

The dissolved oxygen test procedure involves four phases: (1) preparing the reagent solutions, (2) collecting the sample, (3) fixing the sample, and (4) making the test.

PREPARING THE REAGENT SOLUTIONS.—The fixing solutions (Oxygen I, Oxygen II, and Oxygen III) are supplied in proper strength for use in the reagent bottles. (CAUTION: Do not fill the reagent bottles more than half full.)

The sodium thiosulphate solution must be made up fresh once a week. Sodium thiosulphate is supplied in stock solution which is 20 times the proper strength for use in the reagent bottle. To make up the solution for use in the dissolved oxygen test, proceed as follows:

1. Remove the burette-and-stopper assembly from the sodium thiosulphate reagent bottle, and rinse the bottle several times with double-distilled water.
2. Take a 50-ml pipette or a graduate from the boiler water testing cabinet; rinse it with double-distilled water and then with the stock solution of sodium thiosulphate.
3. Use the 50-ml pipette or the graduate to transfer exactly 50 milliliters of the stock solution into the sodium thiosulphate reagent bottle. Fill the reagent bottle to the 1000-milliliter mark with double-distilled water.

4. Put the solid rubber stopper in the sodium thiosulphate reagent bottle, and shake the bottle until the contents are thoroughly mixed.
5. Replace the burette-and-stopper assembly in the neck of the thiosulphate bottle, and fill the burette.
6. On the roughened area above the label of the bottle, write the date.
7. At the end of one week, discard whatever remains of the solution, and make up a fresh solution.

The starch solution used for the dissolved oxygen test must be prepared fresh on the day of the test. This solution should be made up as follows:

1. Rinse the 150-ml beaker with double-distilled water.
2. Fill the beaker three-fourths full of double-distilled water.
3. Place the beaker on the hot plate in the cabinet, and heat the water to the boiling point.
4. Put a mound of soluble starch on the end of the spatula. (The amount should be equal to approximately 1/4 teaspoonful.)
5. Put the starch in the boiling water, and stir the solution for about half a minute with the blade of the spatula.
6. Turn off the hot plate, remove the beaker, and allow the solution to cool.
7. Rinse the starch dropping-bottle with double-distilled water, and fill it with the cooled starch solution.

COLLECTING THE SAMPLE.—Attach the rubber tubing to the outlet nipple of the sample cooler. Insert the glass tubing INSIDE the rubber tubing, and start the water flowing at a fast rate. Allow the hot sample to flow for at least 5 minutes to flush the line and cooler. Then start a flow of cooling water through the cooler, and at the same time throttle back the flow of sample water to about 300 milliliters per minute. (You can determine the rate by noting the length of time it takes for your 300-ml sample bottle to fill up; it should take about 1 minute.)

When the sample water flowing from the cooler is as cool as possible, begin to collect your sample. Insert the glass

tubing in a clean sample bottle, making sure that the end of the glass tubing is almost at the bottom of the bottle. Allow the sample water to flow continuously for at least 7 times the period required to fill the bottle the first time. (If you are filling the sample bottle at the proper rate, this means that you should allow the sample water to flow for 7 minutes.)

Keep the glass stopper wet in the water which overflows from the bottle. Slowly, without interrupting the flow, withdraw the glass tubing from the bottle and insert the stopper in the neck of the sample bottle IMMEDIATELY. Give the stopper a twist to make sure that it is properly fitted. Hold the stopper in place and invert the bottle. If a bubble (even a very small one) appears when the bottle in inverted, discard the sample and collect a new one. Follow the procedure described until you obtain a sample which is entirely free of bubbles.

FIXING THE SAMPLE.—After a satisfactory sample has been collected, it must be fixed. Note that, in the following instructions for fixing a sample, the pipettes are identified as Oxygen I pipette, Oxygen II pipette, and Oxygen III pipette, to indicate the solution.

1. Put the plug in the stopcock of the Oxygen II pipette. This plug is normally stored in water in the beaker, when the testing equipment is not in use. The plug must be wet when it is put into the stopcock.
2. Close the stopcocks on all three pipettes.
3. Using the aspirator bulb, fill each pipette with its proper solution. Be careful that you do not force excess reagent out of the vent hole. When you stop pressing on the aspirator bulb, excess reagent will siphon back into the bottle. Drain a small amount from each pipette into the 150-ml beaker, so that each pipette tip is full of reagent and without any air bubbles. Discard the drained reagent and rinse the beaker. Fill the three pipettes again.
4. Remove the stopper from the filled sampling bottle, and raise the bottle onto the tip of the Oxygen I pipette until the tip is submerged in the sample water.

Open the stopcock on the pipette and allow the contents to drain into the sample.

5. As the level in the pipette drops into the tip, lower the sample bottle from the tip of the Oxygen I pipette. Close that stopcock, and immediately raise the sample bottle onto the tip of the Oxygen II pipette until the tip is submerged in the sample water. Open the stopcock of the Oxygen II pipette, and allow the Oxygen II pipette to drain completely into the sample bottle; lower the sample bottle as the liquid level drops into the pipette tip.
6. Replace the stopper in the sample bottle, and close the stopcock on the Oxygen II pipette.
7. Pour off the excess solution above the stopper of the sample bottle.
8. Hold the neck of the sample bottle between two fingers, with the thumb on top of the stopper. Swirl the sample bottle until the contents are thoroughly mixed.
9. Allow the sample to stand until the precipitate has settled so that the sample is clear to below the shoulder of the bottle.
10. Remove the stopper, and raise the sample bottle onto the tip of the Oxygen III pipette until the tip is submerged in the sample water. Open the stopcock on the Oxygen III pipette.
11. When the contents of the pipette have drained into the sample, close the stopcock. Replace the stopper in the sample bottle, and swirl the bottle again to mix the contents.
12. When all of the precipitate has dissolved and the sample is a clear, amber color, it is fixed. The sample may now be exposed to the air.

MAKING THE TEST.—The sample should be tested immediately after it is fixed. Testing should be completed within 15 minutes after the sample has been fixed, and preferably within 30 minutes after it has been collected. To test the fixed sample, proceed as follows:

1. Cool the sample to below 70° F. If necessary, place the TIGHTLY STOPPERED sample bottle in cold water until the sample is cool enough to test. CAUTION: DO NOT submerge the bottle!
2. Using the aspirator, fill the sodium thiosulphate burette to its tip. Refill it, and allow it to drain down to zero.
3. Place the iron ring in the holder which is located between the sodium thiosulphate bottle and the rack for sampling bottles.
4. Place the clean casserole in the ring beneath the tip of the thiosulphate burette.
5. Pour off any liquid above the stopper of the sample bottle. Remove the stopper, and pour the entire contents of the sample bottle into the casserole.
6. Add 10 drops of starch solution from the dropping-bottle to the sample in the casserole. (The starch solution must be made up fresh on the day of the test.)
7. If the solution does not turn blue, report the dissolved oxygen content of the sample as ZERO.
8. If the solution does turn blue, add thiosulphate solution from the burette, drop by drop, stirring continuously with a glass rod or a piece of glass tubing. Keep adding drops of thiosulphate and stirring until the blue color just disappears. Read the burette, and multiply the reading by 0.2 to obtain the dissolved oxygen content of the sample in parts per million. For example,

   Burette reading $= 0.3$

   $0.3 \times 0.2 = 0.06$ ppm dissolved oxygen.

QUIZ

1. What are the three parts of a feed water system?
2. What is the function of a condensate system?
3. What are the five types of fresh water drains?
4. What type of pump was used in the earliest open feed systems to remove both air and condensate from the main condenser?
5. What were the two main sources of oxygen contamination in the earliest open feed systems?
6. List the appropriate boiler operating pressures for each type of feed system.
7. What is the main disadvantage of the vacuum-closed feed system?
8. In a pressure-closed feed system, what condensate lines are under vacuum?
9. What vacuum is maintained in the main condenser?
10. Why is condensate pumped through the air ejector condenser, the gland exhaust condenser, and the vent condenser?
11. Why is condensate recirculation necessary?
12. Where does makeup feed enter a feed system?
13. What three functions does the deaerating feed tank have?
14. What pressure is maintained in the deaerating feed tank?
15. What units are used for reporting the results of feed water tests?
16. What is the maximum allowable chloride content of water in reserve feed tanks?
17. Suppose that you are making a feed water chloride test, using a 100-ml sample. If the burette reading is 1.6, what is the chloride content of the feed water?
18. How would you report the chloride content of feed water, on the basis of a salinity indicator reading of 0.8 grains of sea salt per gallon?
19. What is the maximum allowable hardness of makeup feed water?

CHAPTER 10

FUEL OIL SYSTEMS

As a Boilerman, you must have a thorough knowledge of fuel oil systems in general, and of the particular fuel oil system on your own ship. The information given in this chapter will help you to learn about fuel oil systems in general. For a knowledge of the system on your own ship, you should study the ship's blueprints and diagrams. Further information on fuel oil systems may be found in BuShips *Manual*, chapter 55.

The fuel oil system consists of all spaces designated for the storage of fuel oil; the lines and pumps required to transfer fuel oil; and all apparatus used for heating, straining, measuring, and burning the oil. The essential units in a fuel oil system are:

1. Fuel oil tanks
2. Piping systems
3. Fuel oil pumps
4. Fuel oil meters
5. Fuel oil heaters
6. Strainers
7. Fuel oil burners.

Before discussing these component parts in detail, let's get an overall view of the fuel oil system by tracing the path of the oil from the time it is taken aboard until it is mixed with air and burned inside the boiler furnace. An elementary diagram of a fuel oil system is shown in figure 10–1.

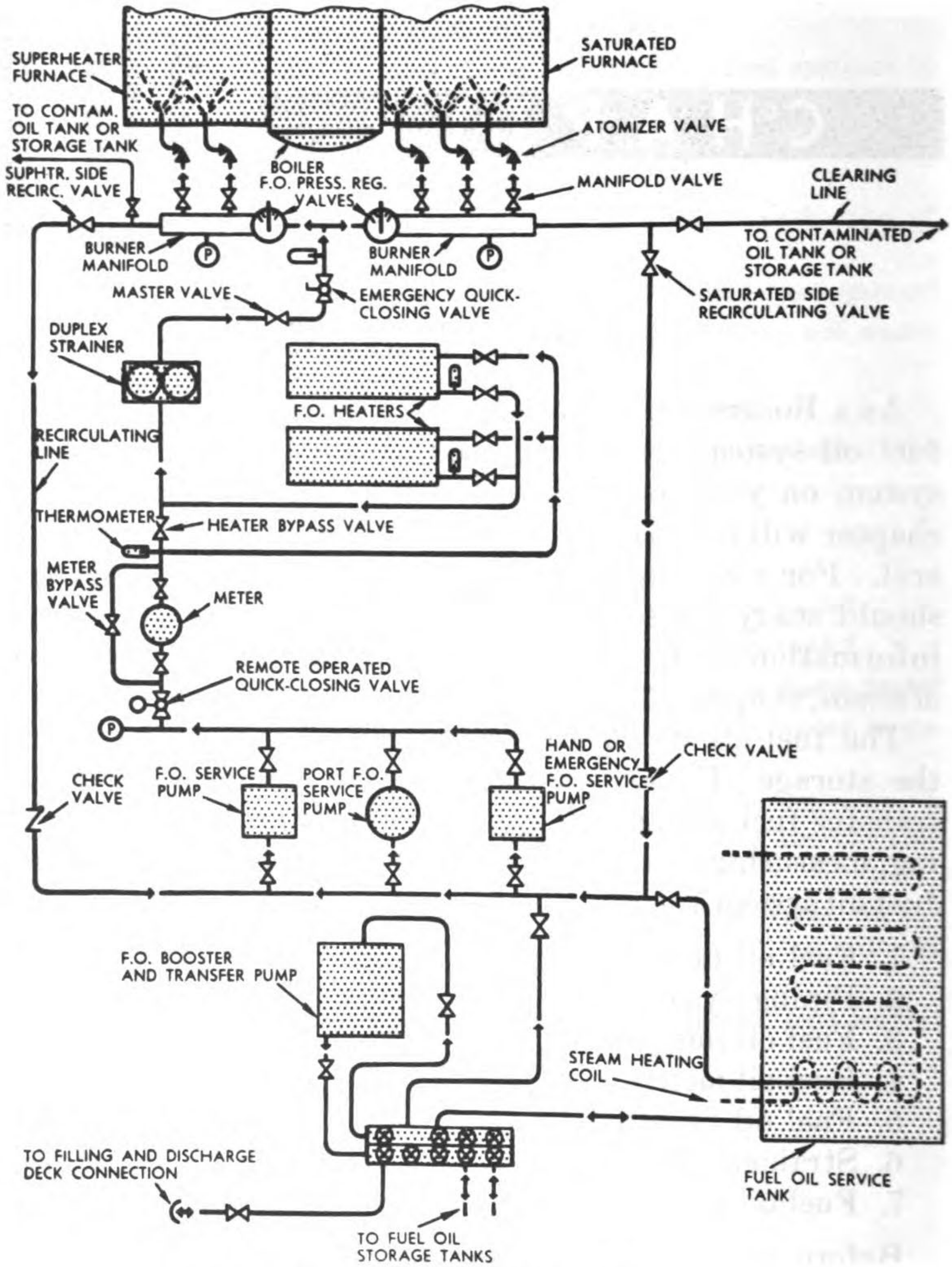


Figure 10–1.—Fuel oil system.

THE PATH OF OIL

Fuel oil is taken aboard by means of fueling trunks, on smaller ships, or special connections, on larger ships. Once aboard the ship, the oil is piped into storage tanks. The main fuel oil storage tanks are an integral part of the ship's structure. They may be located forward and aft of the enginerooms and firerooms, abreast of these spaces, and in double-bottom compartments. However, fuel oil storage tanks are never located in double-bottom compartments directly under boilers.

From the storage tank, the oil passes through a manifold and then to the fuel oil booster and transfer pump. This pump can either take suction from or discharge to the manifold. The primary function of the fuel oil booster and transfer pump is to transfer oil from storage tanks to fuel oil service tanks. However, the pump can also be used as a booster pump in case the fuel oil service pump cannot take suction; in this case, the booster and transfer pump discharges oil directly to the suction side of the fuel oil service pump.

Oil from the fuel oil service tank is pumped to the boiler by the fuel oil service pump. This pump takes suction from the service tank and discharges through the remote-operated quick-closing valve, the fuel oil meter (or the meter bypass), the fuel oil heaters (or the heater bypass), the duplex strainer, the master valve, and the emergency quick-closing valve, into the burner manifolds.

From the burner manifolds, the fuel oil passes through manifold root valves to each burner line. The pressure of the oil going to the burners is controlled by a pressure-regulating valve (micrometer valve) on each burner manifold.

The fuel oil finally enters the burner through an atomizer valve or needle valve, and is burned in the boiler furnace.

Fuel Oil Tanks

Three kinds of fuel oil tanks are required in a fuel oil system: (1) storage tanks, (2) service tanks, and (3) settling

or contaminated oil tanks. As we have seen, fuel oil is transferred from storage tanks to service tanks, and all oil for immediate use is then drawn from the service tanks.

Contaminated oil tanks are used to store oil which is known or suspected to be contaminated with water or other impurities. The impurities are allowed to settle and are then removed from the tank by the bilge or deballasting pump, through a low suction or stripping system connection. The remaining usable oil is then transferred to a service tank or a storage tank, as appropriate.

Fuel oil tanks are very carefully constructed in order to prevent leakage of oil out of the tanks or leakage of water into the tanks. Bulkhead seams are usually welded. All fuel oil tanks are thoroughly tested during construction, and periodically thereafter.

Fuel oil tanks are vented to the atmosphere by pipes leading from the tops of the tanks to locations above decks. These vent pipes allow the escape of vapor, when the tanks are being filled, and the entrance of air, when the tanks are being emptied.

Fuel oil tanks are also supplied with manholes, overflow lines, sounding tubes, heating coils, and several lines for filling, emptying, and cross-connecting.

Fuel Oil Piping Systems

Fuel oil piping systems include lines for filling, emptying, stripping, cross-connecting, ballasting, and deballasting all of the fuel oil tanks. In addition, fuel oil piping systems include all the lines which connect the various units of the fuel oil service system in the fireroom.

In general, fuel oil piping systems may be considered as four distinct systems. The FILLING AND TRANSFER SYSTEM usually consists of two large lines, one on either side of the ship, running fore and aft. Cross-connections join these mains to the booster and transfer pumps. Risers are provided fore and aft for taking on or delivering fuel. Lines and manifolds are provided so that the booster and transfer pumps can transfer oil from one tank to another, and so that

they can discharge to the fuel oil service pump suction when necessary.

The FUEL OIL SERVICE SYSTEM consists of a service main, manifolds, service pumps, meters, heaters, strainers, burner manifolds, and the burner lines. Many installations are arranged so that any fuel oil service pump can take suction from any fuel oil service tank. Fuel oil service systems (including fuel oil heaters) must be subjected to a pressure test at least once a quarter, and at any time when the system has not been used for a period of one week. The system is tested to an oil pressure equal to the authorized setting of the fuel oil service pump discharge relief valve. If the system has undergone extensive repairs or alterations, it is usually tested to an oil pressure equal to 150 percent of designed operating pressure.

The STRIPPING SYSTEM serves to clear fuel oil storage tanks and fuel oil service tanks of sludge and water, before oil is pumped from these tanks by the booster and transfer pump or the fuel oil service pump. The stripping system is connected through manifolds to the bilge pump or, in some installations, to special stripping system pumps. The stripping system discharges the contaminated oil overboard or to the contaminated oil tanks.

Most combat vessels are provided with a BALLASTING AND DEBALLASTING SYSTEM. This system allows certain fuel oil tanks to be flooded by use of the firemain system or through direct-connected sea valve arrangements, when such flooding is required for stability control. These tanks are drained through the main drainage system or, in some installations, through the stripping system.

Fuel Oil Pumps

The fuel oil system on most naval vessels includes the three kinds of pumps which we have already mentioned: fuel oil service pumps, fuel oil booster and transfer pumps, and fuel oil stripping pumps. In modern installations, these pumps are almost always positive-displacement rotary pumps.

Service pumps take suction from the service tanks or from the booster and transfer pump discharge, and supply oil to the burners at the boiler fronts. Three classes of fuel oil service pumps are used: main service pumps, port-use service pumps, and hand or emergency service pumps. Main service pumps are usually turbine driven; port-use pumps are driven by electric motors. Hand fuel oil service pumps are used to supply fuel oil for lighting off boilers, when electricity or steam is not available.

Booster and transfer pumps take suction from the storage, service, and contaminated oil tanks, through the manifold. These pumps are arranged to discharge to all storage, service, and contaminated oil tanks; to the fuel oil service pump suction; and to deck filling connections used for delivering oil to other ships.

The stripping pumps take suction from the storage and service tanks, and discharge overboard or to the contaminated oil tanks.

The various fuel oil pumps take suction from storage and service tanks at different levels. Stripping system pumps have low-level suction connections. Fuel oil service pumps have high-level suction connections. Booster and transfer pumps take suction above the stripping system pumps, but below the fuel oil service pumps.

Fuel Oil Meters

The type of fuel oil meter most commonly used in naval fuel oil systems is shown in figure 10–2. This is usually referred to as a DISK-TYPE meter.

The flow of oil through the meter causes the disk to rock around on its lower spherical bearing surface. The disk is not free to rotate, being held in place by a fixed diaphragm which runs vertically through a slot in the disk. As the disk rocks around, the pin which projects from the upper spherical bearing surface moves with a rotary motion, and rotates the gears which actuate a counting device on the top of the meter.

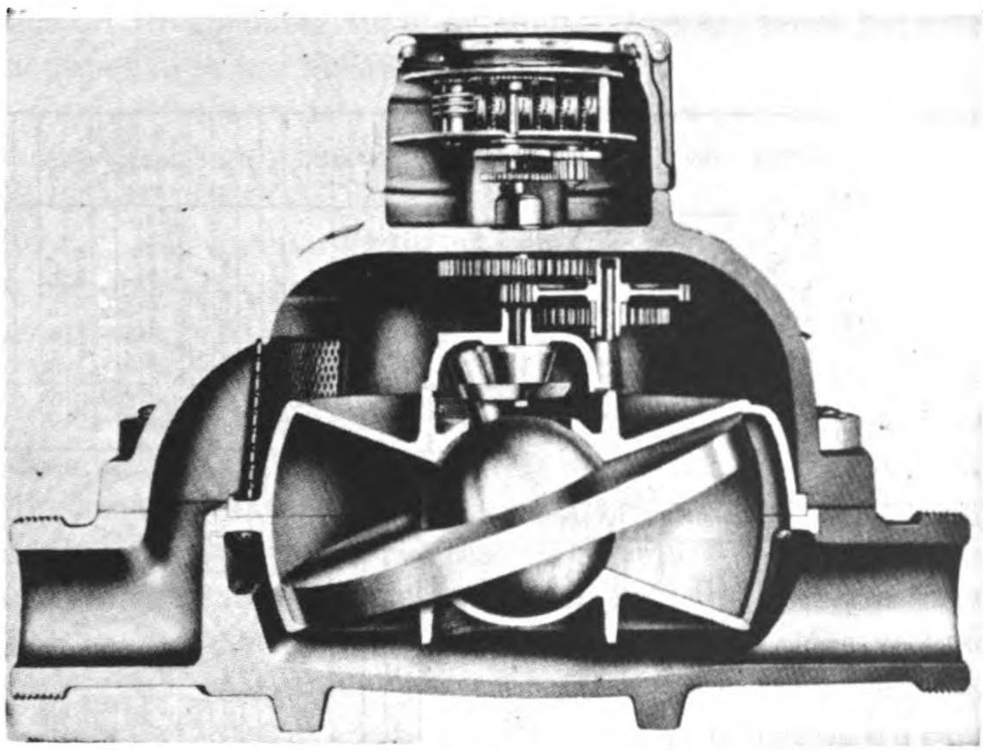


Figure 10–2.—Disk-type fuel oil meter.

This type of fuel oil meter is rugged, accurate, and reliable. It requires little attention, provided the strainers in the line to the meter are kept clean. If any foreign matter gets into the meter itself, the meter reading will not be accurate.

Fuel Oil Heaters

Fuel oil heaters are installed in the oil supply lines to the boilers, on the discharge side of the fuel oil service pumps. Heaters are used to heat the oil and thus reduce its viscosity so that it can be easily atomized. Steam is used as the heating agent.

There are several types of fuel oil heaters approved for naval use. Figure 10–3 shows the G–fin type of heater which is in quite common use. The heating unit in this type of heater consists of several seamless steel inner tubes, through which the steam flows. The inner tubes have longitudinal fins welded to their outer surfaces; the fins serve to increase the size of the heat-transfer surface. Each inner tube is

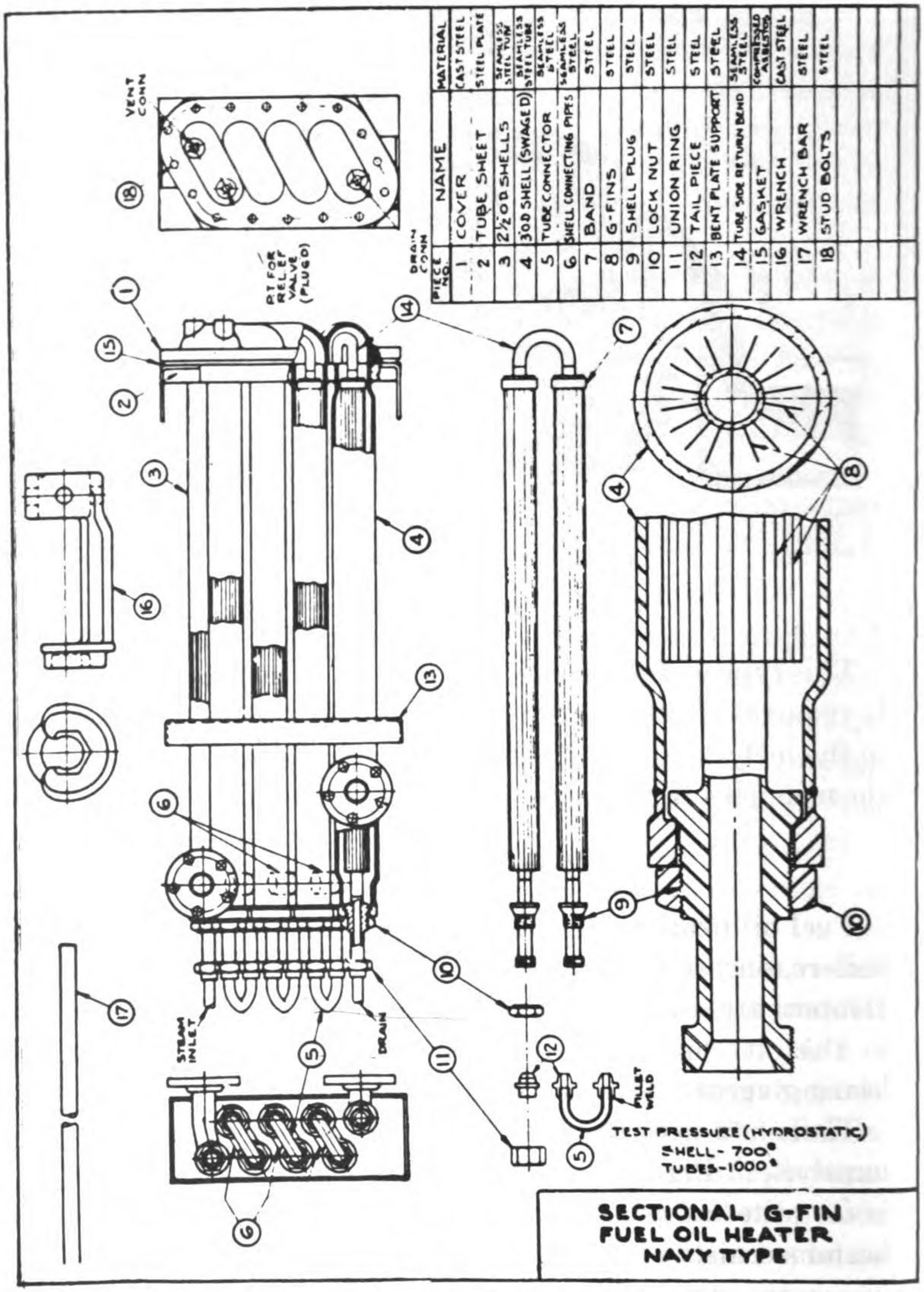


Figure 10–3.—G-fin type of fuel oil heater.

encased in an outer tube, or shell. The oil flows between the inner tube and the shell.

Fuel oil heaters often contain more than one heating unit, and the units may be cut in separately. The number of heaters or heater units in use at any time depends upon load conditions. As a general rule, it is better to operate one heater or one heating unit at full capacity rather than two heaters or units at partial capacity.

Water must not be allowed to accumulate on the steam side of fuel oil heaters, since it would partially blanket the tubes and so reduce the heating capacity of the unit. In idle heaters, water accumulation tends to cause corrosion. Drain lines and fittings are installed to allow complete drainage of the heaters; steam traps are fitted in the drain lines.

Other fittings usually found on fuel oil heaters include vents, relief valves, connections for gages and thermometers, and oil drain connections.

Special precautions must be taken to detect any leakage of oil into the steam side of heaters. Heater drains must be inspected hourly for the presence of oil. If oil is found in the drains, the defective heater must be secured and the drains must be run to the bilges. If only one heater is in use when the oil leakage is discovered, a second heater must be cut in before the leaking one is secured.

Heating the fuel oil to too high a temperature will result in excessive fouling of the heater. Excessive heat causes the oil to break down and deposit carbon on the tubes. For this reason, it is particularly important to control the heater temperature at all times.

Fuel oil heaters are normally cleaned when boilers are being overhauled. If performance indicates that a heater is fouled, however, it should be cleaned at the earliest opportunity. Mechanical methods of cleaning are approved for some types of heaters, but are not allowed for others. The standard method of cleaning fuel oil heaters is known as the Fitzgerald method; it is a chemical treatment involving the use of trichloroethylene in either liquid or vapor form. All safety precautions must be observed in using this chemical,

as it is extremely dangerous to personnel if it is inhaled or if it comes in contact with the skin for any length of time.

When it is necessary to open up a fuel oil heater for repairs, inspection, or overhaul, be sure that all valves in the lines to and from the heater are closed, wired, and tagged. Remove the oil drain plug in the cover plate and allow the oil to drain from the heater.

In order to remove the heating elements from the shells, disconnect the union joints. These are steam fittings which hold tube connectors to the ends of the tubes. Release the lock nuts and remove them by screwing them over the upper half of the unions. (The union thread is the same as the lock nut thread.) Then remove the cover plate and pull the heating elements out of their shells. It is not necessary to disturb the external oil connections when removing the heating elements.

Sludge or dirt may be removed from the fin surfaces with a special scraping tool. This tool is shaped somewhat like a hoe, with the blade formed to fit between two fins.

For all repairs such as renewing tubes, tube sheets, heads, and gaskets, consult the manufacturer's instruction book for the particular piece of equipment you are repairing.

Strainers

Strainers are fitted into fuel oil lines for the purpose of catching solid particles of foreign matter in the oil. On some older vessels, basket-type strainers were installed on the suction side of the fuel oil pumps. However, these suction strainers are not required by current Navy specifications.

Duplex, high-pressure, basket-type strainers are installed on the discharge side of the fuel oil service pumps, usually between the heater and the burner manifold. After the oil has been heated, it is very fluid and readily gives up any foreign particles. These strainers are installed so that the oil flows from the center of the basket to the outside, leaving dirt and sediment in the basket. Duplex strainers have a valve arrangement which allows one strainer to be removed

for cleaning while the other strainer remains in service. Edge-filtration type filters are used on the discharge side of the fuel oil service pump in some vessels of recent design.

As a matter of routine, strainers should be inspected and cleaned once each day, and more often if necessary. A pressure gage is connected by a three-way valve to each side of the strainer, to indicate the drop in pressure through the basket. Any unusual pressure drop through the strainer is an indication that the strainer needs to be cleaned.

Fuel Oil Burners

Fuel oil burners divide the fuel oil into fine particles which, when mixed with air, are highly combustible. The oil is divided by atomizers; the air, which is supplied by the forced draft blowers, is admitted through air registers.

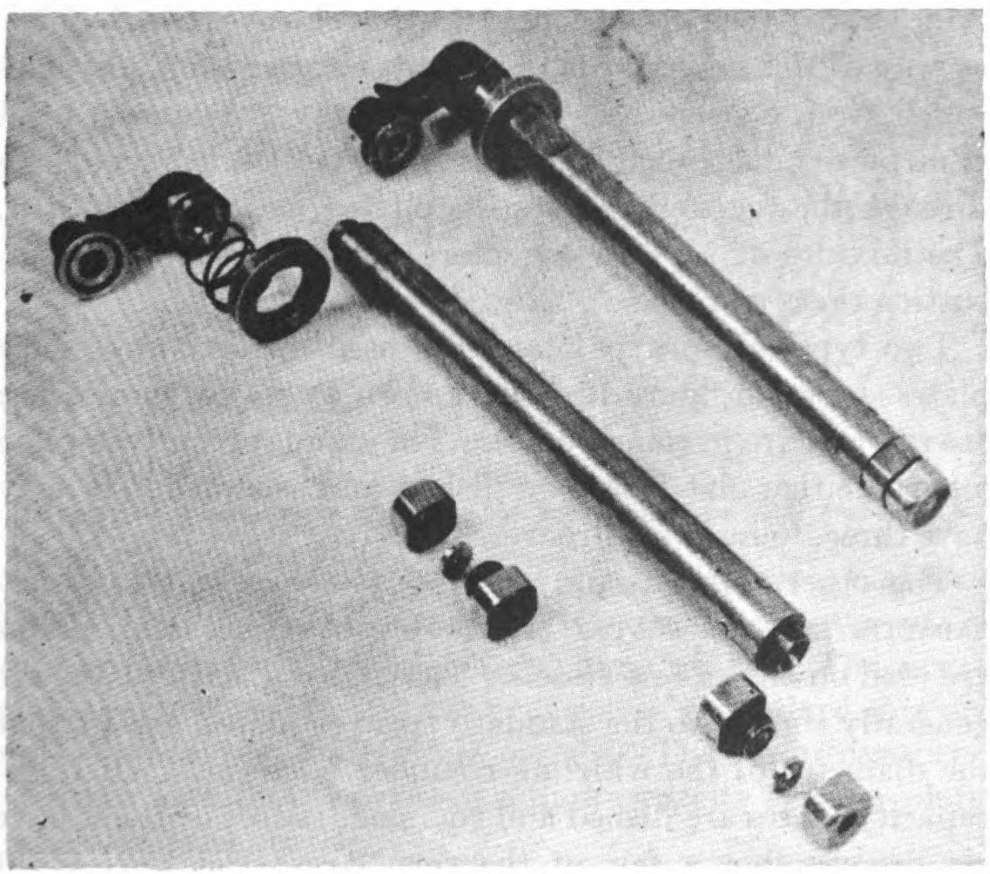


Figure 10–4.—Atomizer assembly.

The burner is mounted on the front of the boiler. The complete burner assembly consists of the atomizer, the air registers, and the valves and fittings needed to connect the atomizer to the fuel line and to control the flow of oil to the atomizer.

An atomizer has a TIP, a SPRAYER PLATE, a NOZZLE, a BARREL, and a GOOSE NECK. These parts are shown in figure 10-4. The barrel is threaded at both ends. The goose neck fits on the outer end of the barrel; the nozzle, sprayer plate, and tip fit on the end which projects into the furnace.

Oil is forced under high pressure through the burner barrel. It goes through the nozzle, which directs the oil to the grooves of the sprayer plate. These grooves are shaped so that the oil is given a high rotational velocity as it discharges into a small cylindrical "whirling chamber" in the center of the sprayer plate.

The whirling chamber is coned out at the end, and has an orifice at the apex of the cone. As the oil leaves the chamber by way of this orifice, it is broken up into very fine particles which form a cone-shaped, foglike spray. A strong blast of air, which has been given a whirling motion in its passage through the register, catches the oil fog and mixes with it. The mixture of air and oil enters the furnace, where combustion takes place.

Two types of sprayer plates are used in the Navy. The plates shown in figure 10–5 are known as STANDARD SPRAYER PLATES, and are in common use. The standard sprayer plate may be either flat-faced, or dished and rounded. It may have three, four, or six grooves.

The other type of sprayer plate is the STANDARD HIGH-CAPACITY SPRAYER PLATE. At the present time, these plates are used on only a few vessels. The high-capacity plates are generally similar to the standard sprayer plates, except that the diameter of the whirling chamber is larger. All high-capacity plates are dished and rounded. Most of them have six grooves, but a few of the very large sizes have eight grooves.

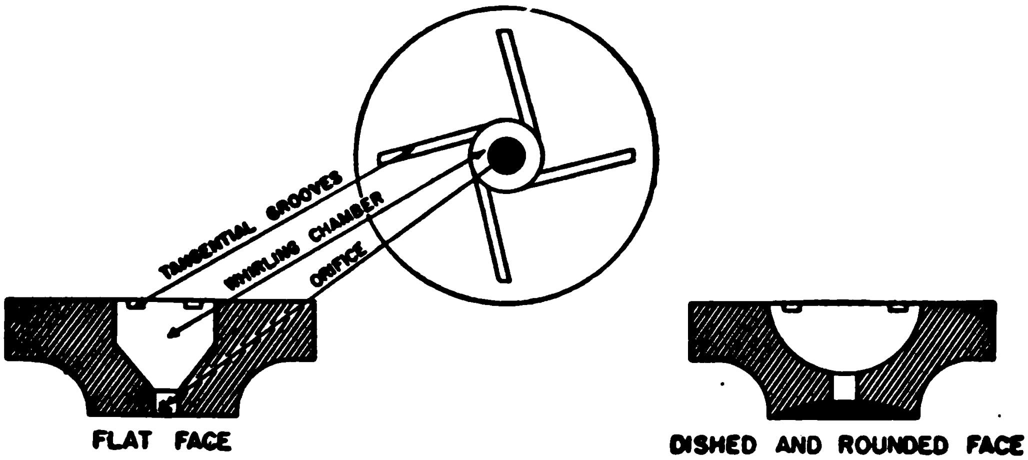


Figure 10–5.—Standard sprayer plates.

The two types of nozzles now used are the STANDARD NOZZLE and the SEMIWIDE-RANGE NOZZLE. These two types are shown in figure 10–6. The standard nozzle has four oil holes, and the semiwide-range nozzle has six. When the present supply of semiwide-range nozzles is exhausted, only standard nozzles will be issued.

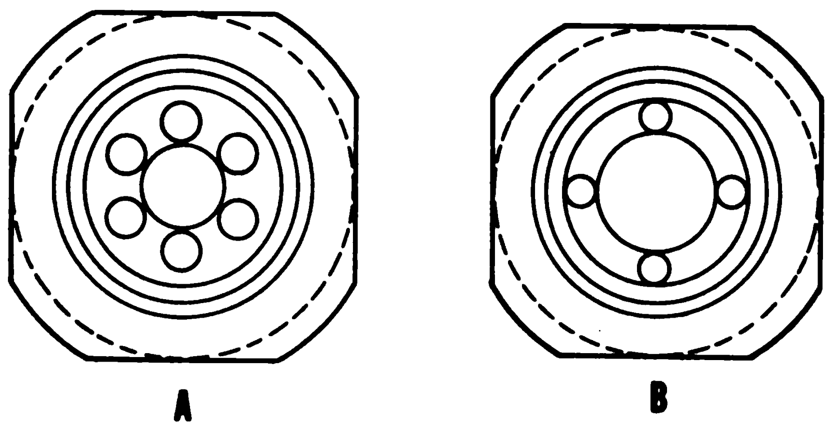


Figure 10–6.—Atomizer nozzles. (A) Semiwide-range. (B) Standard.

Sprayer plates and nozzles are used in several combinations. The STANDARD ATOMIZER ASSEMBLY consists of a standard sprayer plate and a standard nozzle. The SEMIWIDE-RANGE ATOMIZER ASSEMBLY consists of a standard sprayer plate and a semiwide-range nozzle. The HIGH-CAPACITY ATOMIZER ASSEMBLY consists of a high-capacity sprayer plate and a standard nozzle.

Sprayer plate size is indicated by four numbers which are

stenciled on the face of the plate. The first two digits indicate the bore of the orifice (United States standard drill size). The second two digits are the quotient (with decimal point left out) of the combined cross-sectional area of the sprayer plate grooves divided by the area of the orifice.

When the smaller sizes of sprayer plates are used, oil pressures should be maintained between 125 and 300 psi, depending on the firing rate required. The lower pressure of 125 psi should not be used except to take care of temporary maneuvering conditions. When the larger sizes of plates are used, every effort should be made to keep the oil pressure between 200 and 300 psi. The higher oil pressures are desirable because they ensure better atomization of the oil.

A special type of atomizer which is used on many converted merchant vessels and also on some new construction (including DL's) is known as a RETURN FLOW OF VARIABLE CAPACITY ATOMIZER. A return flow atomizer is shown in figure 10–7. In this type of atomizer, the oil supply pressure is kept constant and the oil flow to the furnace is controlled by regulating the oil return pressure. The supply oil enters through the tube-like opening down the middle of the atomizer, and passes through the sprayer plate. The tangential slots in the

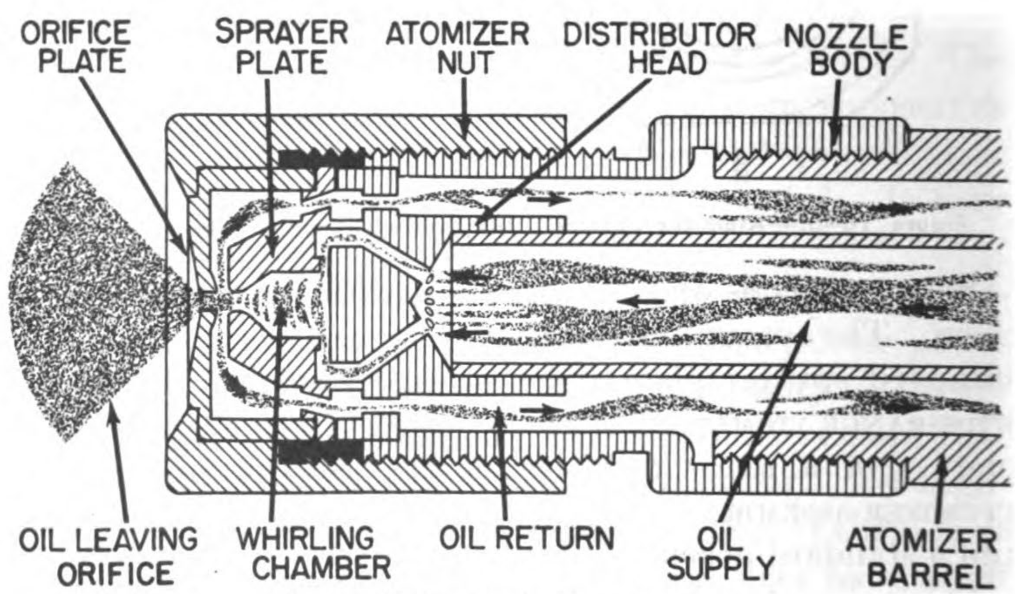


Figure 10–7.—Return flow atomizer.

sprayer plate cause the oil to enter the whirling chamber with a rotary motion. As the rotating oil reaches the return annulus, centrifugal force causes a certain amount of oil to go into the return annulus; the amount of oil thus returned is determined by the back pressure in the return line, and this pressure is, in turn, varied by the extent to which the return line control valve is open.

The oil which is not returned emerges from the orifice plate in the form of a hollow, conical spray of atomized oil. The amount of oil burned, therefore, is the difference between the amount of oil supplied and the amount returned.

Another type of return flow atomizer is designed so that the oil enters through an annulus and returns through the tube-like central opening. In this atomizer, the amount of oil delivered to the furnace is controlled by regulation of both the supply pressure and the return pressure.

An AIR REGISTER consists of three main parts: (1) air doors, (2) a diffuser, and (3) air foils. The air doors serve to open or close the register, as necessary; they are ordinarily kept either fully open or fully closed. When the air doors are open, air rushes in and is given a whirling motion by the diffuser plate. The diffuser causes the air to mix evenly with the oil, in such a way as to prevent the flame being blown from the atomizer. The air foils guide the major quantity of air and cause it to mix with the larger oil spray beyond the diffuser. Figure 10–8 shows the arrangement of air register parts in a burner assembly.

Since the diffuser plate is fastened to the distance piece, and since the atomizer barrel slides into the distance piece, the distance between the face of the atomizer tip nut and the diffuser plate is determined by the setting of the distance piece. This setting is a relatively permanent one, and varies for different types of burners. Always consult the manufacturer's instruction book to get the correct setting for a particular burner.

It should be noted that this adjustment of the distance piece is very rarely required. Do not confuse this permanent adjustment with the adjustment of the entire assembly—dis-

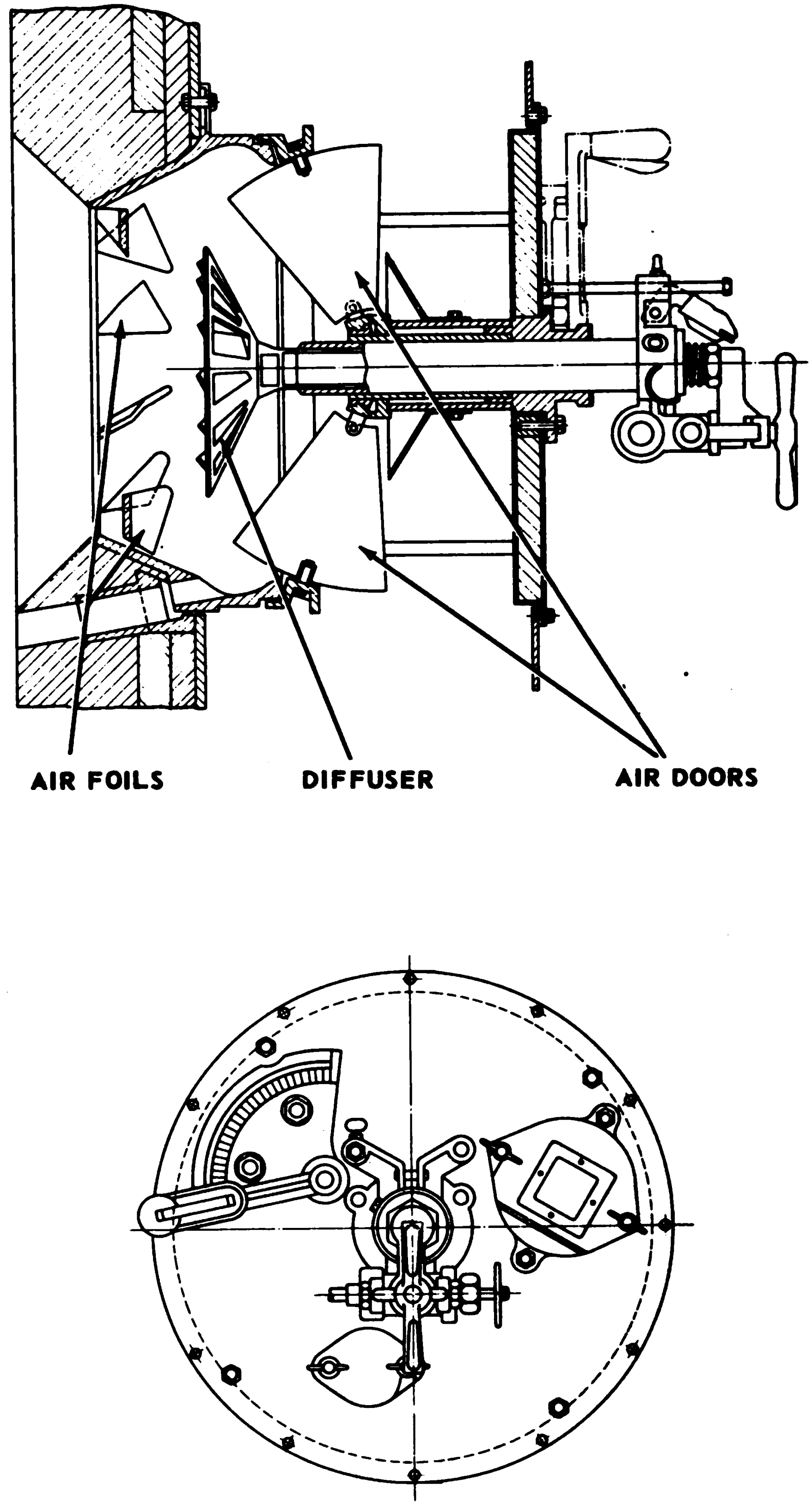


Figure 10–8.—Burner assembly.

tance piece, atomizer, and diffuser plate—which must be made each time the burner is lighted off.

It is very important that the air doors operate properly. They must be examined periodically, and straightened or renewed as necessary. All parts of the register assembly should be kept entirely free of oil, carbon, and dirt. Throttling of air doors should be avoided, since this will tend to cause carbon deposits in the register and on the refractory cone, with consequent leakage of oil into the boiler fronts. Throttling of air doors is not necessary when air pressure is properly controlled by the blower.

As a matter of routine, you should inspect and clean drain holes and drip pans. Drain holes can be kept open by punching through them with a metal rod. Oil must never be allowed to accumulate in drip pans or bilges, or on floor-plates or boiler fronts. Any accumulation of oil increases the possibility of fire.

Proper atomization of the oil—and, therefore, proper operation of the burner—cannot be achieved unless all atomizer parts are kept clean and in good condition. Most damage to sprayer plates is caused by careless handling and inadequate cleaning. Any change in the dimensions of atomizer parts will have a noticeable effect on results. A tiny scratch or a speck of carbon in a sprayer plate will cause the spray to be uneven.

Atomizers must be changed at least once each watch, and oftener if they appear to be clogged. The atomizer should be drained of all oil and then blown out with steam. (Most firerooms have a steam line rigged for this purpose.) The tips, sprayer plates, and nozzles must be removed as soon as possible and immersed in a pan of kerosene or Diesel oil. After the carbon has softened up, the parts should be thoroughly cleaned and polished.

Sprayer plate grooves, whirling chambers, orifices, hubs, and faces should be cleaned with wooden sticks. NEVER use steel wire, steel wool, steel tools, or any abrasive substance to clean any part of the tip, nozzle, or sprayer plate. An electric motor is sometimes used in polishing atomizer

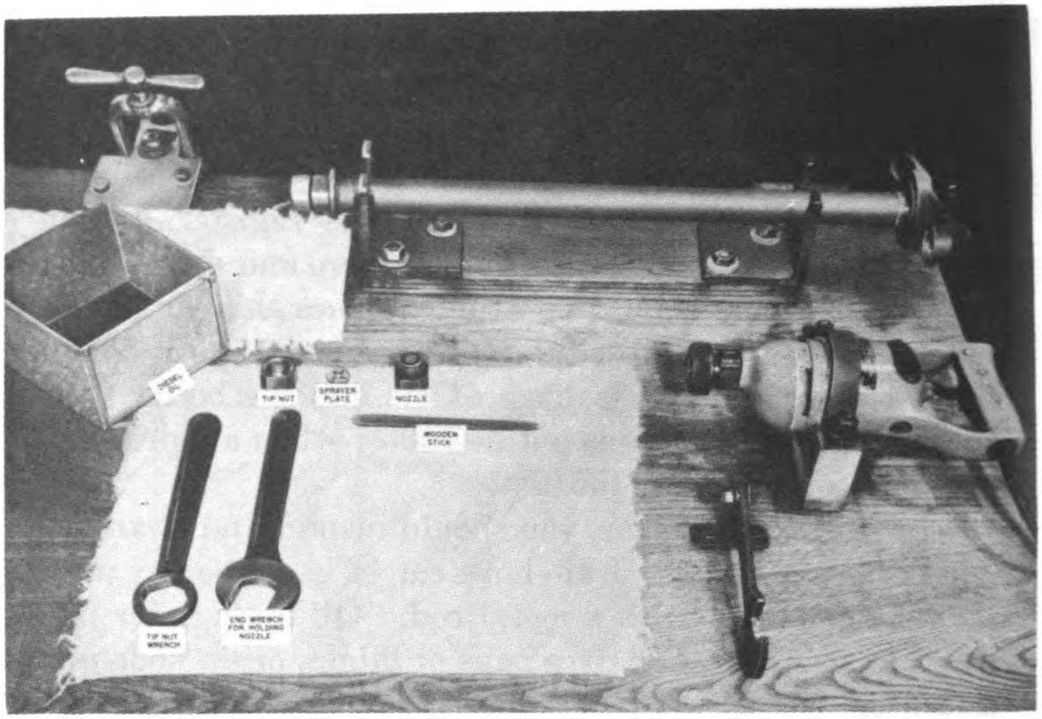


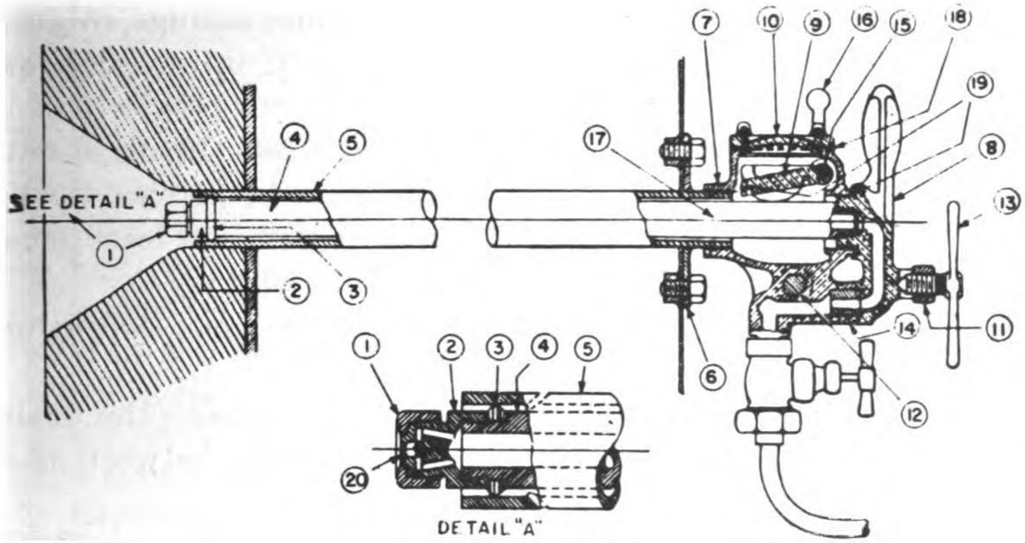
Figure 10–9.—Atomizer cleaning equipment.

parts; the part is held in a chuck attached to the motor, while a light grade of lube oil is applied with an approved buffing brush. Figure 10–9 shows an atomizer cleaning bench with the necessary equipment.

If a clean sprayer plate fails to give an even and finely atomized spray, it should be discarded. As a rule, a sprayer plate should be discarded when the discharge orifice is 0.005 inch oversize, or when the sum of the dimensions of the depth and the width of the grooves exceeds that of the original dimensions by 0.005 inch.

After being cleaned, all atomizer parts should be wiped with a heavy lube oil and stowed in the drawers or lockers provided. If extra sets of burners are made up for emergency use, be sure that they are correctly assembled and perfectly clean. On most ships, racks for these standby burners are located in front of the boilers.

On combatant ships, each boiler is provided with a special SMOKE-SCREEN BURNER. Regular burners must not be used for making smoke, where smoke-screen burners are fitted. A smoke-screen atomizer is similar to a standard atomizer, but



PARTS LIST

1. Atomizer tip
2. Nozzle body
3. Ring for atomizer barrel
4. Atomizer barrel
5. Jacket tube
6. Jacket tube flange
7. Atomizer body
8. Atomizer handle
9. Internal check valve
10. Atomizer body cover
11. Clevis
12. Clevis pin
13. Atomizer screw
14. Atomizer housing bushing
15. Internal valve shaft
16. Internal valve lever
17. Atomizer body set screw
18. Atomizer body cover gasket
19. Atomizer body and check valve gasket
20. Sprayer plate

Figure 10–10.—Smoke-screen burner.

it has a longer barrel and a special nozzle. A large-capacity sprayer plate is used with the smoke-screen burner.

A special opening in the boiler front admits the end of the atomizer assembly, which is fitted so as to prevent the entrance of air. Thus the oil is forced into the firebox, without being mixed with air. Since the oil cannot burn completely, smoke is formed.

A smoke-screen burner is shown in figure 10–10.

SAFETY PRECAUTIONS

The following safety precautions must be observed by all personnel concerned with fuel oil and fuel oil systems:

1. Use only approved types of protected lights in the fireroom. Do NOT use open lights or flames of any kind, except as specifically permitted.
2. Do not use any unprotected lights in fuel oil tanks, or within 50 feet of fuel oil hoses or vents.

3. Do not allow oil to accumulate in inner casings, bilges, etc. Whenever oil is spilled, wipe it up as soon as possible.
4. Be sure that the burner is lighted when the oil is cut in, so that oil will not accumulate on the furnace floor.
5. Inspect the drain holes of the air registers at least once each watch, and clean them when necessary.
6. Keep all fire-fighting equipment in good working order.
7. Never raise the temperature of fuel oil above the flash point in any part of the system except between the heaters and the atomizers.
8. Do not allow oil to be recirculated after it has reached a temperature of 150° F.
9. Never raise the temperature of fuel oil above 120° F in fuel oil tanks; or, if the tanks are next to a magazine, never allow the oil to become hot enough to maintain the temperature of the magazine above 90° F.
10. When the fuel oil system is designed for 300 psi, the oil pressure in any part of the system should not exceed that necessary to produce 300 psi at the burner manifolds. At no time should the fuel oil service pump discharge pressure exceed 350 psi.

Further precautions concerning fuel oil equipment and fuel oil systems can be found in BuShips *Manual*, chapter 51 and chapter 55, and in appropriate manufacturers' instruction books. In this training course, see also the safety precautions given in chapter 15.

QUIZ

1. What are the basic units in a fuel oil system?
2. What is the primary purpose of the fuel oil booster and transfer pump?
3. What valve controls the pressure of the oil going to the burners?
4. What three kinds of tanks are used in most shipboard fuel oil systems?
5. What four fuel oil piping systems are found on most ships?
6. Which fuel oil pumps take low-level suction from fuel oil storage and service tanks?
7. What is the main item of maintenance required for disk-type fuel oil meters?
8. Is it better to operate one fuel oil heater at full capacity, or two fuel oil heaters at partial capacity?
9. How often must fuel oil heater drains be inspected for the presence of oil?
10. What chemical is used in the Fitzgerald method of cleaning fuel oil heaters?
11. At what point in the fuel oil system are duplex, high-pressure strainers installed?
12. How often should fuel oil strainers be inspected and cleaned?
13. What two types of atomizer nozzles are now used in the Navy?
14. What oil pressure should be maintained when the larger sizes of sprayer plates are being used?
15. What are the main parts of an air register?
16. What kind of tools must be used to clean sprayer plates, nozzles, and tips?
17. Why is it important that the burner be lighted when the oil is cut in?
18. In a fuel oil system designed for 300 psi, what is the maximum allowable discharge pressure of the fuel oil service pump?

CHAPTER 11

FIREROOM OPERATIONS

Thus far in this training course, we have taken up the various units and systems required for the operation of a steam plant: boilers, fittings and instruments, pumps, blowers, feed water systems, and fuel oil systems. In this chapter, we will bring much of this information together and see how it is applied to actual fireroom operations—to lighting off, operating, and securing the boilers.

LIGHTING OFF BOILERS

The following instructions for lighting off boilers apply, in general, to most modern express boilers. Special additional instructions for lighting off superheaters are given after the general procedure has been indicated. In all cases, this information should be supplemented by specific operating instructions issued by the Engineer Officer and by the manufacturer of the equipment.

In general, these are the steps to be followed in lighting off a boiler:

1. Remove the stack cover.
2. Inspect the bilges to be sure that they are free of oil. If necessary, wash and pump the bilges.
3. Inspect the bottoms and inner front casings of all air-encased boilers, to see that they are free of oil accumulations. Be sure that the register drip holes are not plugged.

4. Check the fuel oil strainers to be sure that they are clean and in good condition.
5. Inspect all atomizer assemblies. Be sure that they are the correct size, and that they are clean and properly made up.
6. Move all air register doors to be sure that they operate freely.
7. Check individual atomizer (needle) valves and manifold valves. They should be CLOSED.
8. Wipe up all oil from floorplates, etc.
9. Run the forced draft blower, with the air register doors open; this will ventilate the furnace and clear it of accumulated gases.
10. Examine all casing doors to be sure that they are closed and that they are airtight.
11. Open the steam drum aircock and the superheater vents.
12. Check to see that the water gage cut-out valves are open and that the drain valves are closed.
13. Check to see that the surface blow valve and the sea valves are closed and that they are not leaking.
14. Run down or pump down the water in the boiler until it is just out of sight in the 10-inch water gage glass. To do this, you must open the bottom blow valve and open the drain valves to the bilges (including the superheater valves to the bilges). The line to the bilges has a hose connection so that the water can be pumped overboard if desired.
15. After the superheater has been emptied, close the superheater valves to the bilges and open the superheater gravity (open-funnel) drain.
16. Examine the hand gear for lifting safety valves, and operate this gear as far as this can be done WITHOUT lifting safety valves.
17. Open the auxiliary feed stop and check valve, start the emergency feed pump, and bring the water level to about 1 inch above the bottom of the glass in the 10-inch water gage. This procedure fills the economizer with water, tests for possible obstructions in the feed lines and water

gages, and tests the operation of the emergency feed pump.

18. Open the main feed stop and check valve, start the main feed pump, and raise the water level in the boiler about ½ inch. This procedure tests the main feed pump and the lines.
19. Ease up on the boiler main steam stop valve stem, WITHOUT lifting the valve disk off its seat. This procedure will prevent the valve from sticking when it is heated.
20. Check to be sure that all cocks and valves in the line to the steam drum pressure gage are open.
21. Line up the fuel oil system. Open all necessary valves from the service tank to the service pump. Bypass the meter, and open all valves between the service pump and the burner manifold. Open the recirculating valves, and start the service pump.
22. If the oil is very cold and viscous, so that the service pump has difficulty taking suction, use the tank heating coils to warm the oil.
23. Cut in steam to the fuel oil heater.
24. Run the forced draft blower SLOWLY until the first burner is lighted off.
25. When the oil has reached atomizing temperature, partly close the recirculating valves to allow fuel oil pressure to build up to at least 200 psi.
26. Light off the center atomizer or the atomizer designated as No. 1. This atomizer must have a small or "port" size sprayer plate. Use a hand torch for lighting off. STAND CLEAR TO AVOID INJURY FROM A FLAREBACK!
27. As soon as the burner has been lighted, close the recirculating valves and regulate the oil pressure with the micrometer valve.
28. Open the fuel oil meter inlet and outlet valves, and close the meter bypass valve.
29. Light off additional burners, as ordered. When burners are numbered, they must be lighted off in sequence. A HAND TORCH MUST ALWAYS BE USED TO LIGHT THE FIRST

BURNER. ADDITIONAL BURNERS MUST ALSO BE LIGHTED WITH A HAND TORCH UNTIL THE FURNACE BECOMES INTENSELY HOT.

30. Check the level in the water gages as the water in the boiler begins to heat up, and frequently after steam has been formed.
31. Close the steam drum aircock and the superheater vents, after steam has formed and has blown sufficiently to exclude all air from the boiler.
32. Check the steam drum pressure gage to see that it registers pressure, after the aircock and vents have been closed.
33. When the boiler pressure is about 150 to 200 psi below the safety valve reseating pressure, request permission from the officer of the deck to lift safety valves by hand. BEFORE lifting the safety valves, open the superheater drain valves to the bilges to make sure that the superheater is free of condensate. When the boiler pressure is within 100 psi of the safety valve reseating pressure, lift the valves sufficiently to blow any scale or foreign matter from the valve seat.
34. Check the working of the water gages by opening the drains and blowing through.
35. See that the water in the boiler is kept at steaming level.
36. Before cutting the boiler in on the main or auxiliary steam lines, use the bypass valves (if fitted) or crack the boiler stop valve slightly to warm up the lines slowly and to equalize pressure between the boiler and the line. Be sure that the lines are properly drained during the warming-up period.
37. Cut in the boiler when the proper pressure has been reached. (This pressure is given on either the fireroom lighting-off check-off sheet or in the operating instructions posted in your fireroom.) CAUTION: A boiler must first be cut in on the auxiliary steam line BEFORE being cut in on the main steam line.

The following ADDITIONAL instructions for lighting off boilers with integral, UNCONTROLLED superheaters must be ob-

served in order to protect the superheater while steam is being raised in the boiler:

1. On or before lighting the first burner, establish a positive flow of steam through the superheater. Open the superheater protection exhaust valve and the superheater protection steam inlet valve.
2. Be sure the superheater is THOROUGHLY DRAINED at all times. When lighting off, open the gravity (open-funnel) drains and keep them open until the boiler has built up enough pressure (about 50 psi) to allow use of the high-pressure drains.
3. When the steam drum pressure reaches about 100 psi (or, in any case, by the time the steam drum pressure equals the pressure in the superheater protection steam supply line), close the superheater protection steam inlet valve.
4. While raising steam, be very careful not to exceed the allowable rate of combustion. The superheater protection steam supply does not give adequate protection to the superheater at high rates of combustion.
5. Leave the superheater protection exhaust valve open until the auxiliary steam stop is opened and the boiler is furnishing steam to the auxiliary steam line. Then close the superheater protection exhaust valve.

The following precautions must be observed in connection with boilers having integral, CONTROLLED superheaters:

1. The superheater must be THOROUGLY DRAINED at all times. When lighting off, open the low-pressure drains and keep them open until the boiler has built up enough pressure (about 50 psi) to allow use of the high-pressure drains.
2. NEVER LIGHT BURNERS ON THE SUPERHEATER SIDE UNTIL AN ADEQUATE STEAM FLOW HAS BEEN ESTABLISHED THROUGH THE SUPERHEATER! NEVER LIGHT A BURNER ON THE SUPERHEATER SIDE UNLESS ONE OR MORE BURNERS ARE IN OPERATION ON THE SATURATED SIDE!
3. When operating with the saturated side only, keep the air registers tightly closed on the superheater side. This precaution is necessary in order to prevent air leakage

through the superheater furnace, with consequent condensation in the superheater.

4. When there is little or no flow through the superheater, be careful that you do not over-fire the saturated side. Excessive heat from the saturated-side furnace can damage the superheater tubes.

UNDER-WAY OPERATIONS

The number of men on watch in the fireroom varies from one ship to another. If possible, there should be one PO in charge, one checkman for each boiler, one blowerman for each boiler, one burnerman for the saturated side and one for the superheater side of each boiler, one or two men for the auxiliary machinery, one man for the JV phones, and one messenger. On smaller ships, there will, of course, be fewer men available. However, there should always be at least four men on watch, since three of them—the burnerman, the blowerman, and the checkman—cannot leave their stations.

Close cooperation among the men on watch is essential in fireroom operations. One man alone can't operate a boiler—it takes a group of highly skilled men, all thoroughly familiar with the fireroom installation and aware of the relationship of each job to every other job.

PO in Charge of the Watch

As a rule, the petty officer in charge of the watch will be a First Class or Chief Boilerman. However, you should have some understanding of his duties, since emergencies might occur in which a lower-rated man would have to take over the job.

The man in charge is responsible for the safe and efficient operation of all machinery and equipment in the fireroom. When only one fireroom is in operation, the man in charge is generally told to maintain a certain steam pressure and a certain temperature. Other details, such as the number of burners to be used and the control of air pressure, fuel oil, and feed water, are left to his own judgment.

The PO in charge checks constantly to see that each watch

station is properly manned, that all equipment is operating normally, that proper pressures and temperatures are developed and maintained, that the water in the boiler is at the proper level, and that combustion requirements are being met.

The man in charge must be prepared to help at any watch station when necessary. The burnerman, the blowerman, or the checkman may need help at various times.

The man in charge must direct and supervise the lighting off, operating, and securing of boilers, when ordered. He must inform the chief in charge of the engineroom watch and the engineering officer of the watch of operating conditions in the fireroom, as required. He must be constantly alert to indications of faulty operation of equipment. He must make sure that all safety precautions are being observed, and that unsafe operating conditions are not allowed to exist.

Where automatic low-pressure feed water alarms are installed, the man in charge of the watch should check these or have them checked once each watch, to see that they are energized. A low-pressure alarm for the feed booster pump is usually installed on ships which have the feed booster pump in the engineroom and the main feed pump in the fireroom. This alarm system should be tested during the lighting off period, by the following procedure:

1. Start the feed booster pump and bring the discharge pressure up to normal.
2. Energize the low-pressure alarm.
3. Reduce the feed booster pump discharge pressure, to determine whether or not the alarm system is working.

A manually operated (push-button) alarm is sometimes installed. By this means, the checkman can signal low feed pressure to the man at the main feed pump, which is either in the engineroom or on the lower level of the fireroom. The PO in charge of the fireroom watch should make sure that this alarm is tested by the IC Electrician at the proper intervals.

On vessels equipped with multi-element automatic feed water regulators, the PO in charge of the fireroom watch is

responsible for observing the remote water level indicator and making sure that the correct water level is maintained in the boiler. When automatic feed water regulators of this type are installed, they must be kept in use at all times; it is not necessary, therefore, to have a checkman stationed at the feed check valve.

When the engineering officer of the watch has obtained permission from the officer of the deck, the fireroom will be instructed to blow tubes. The man in charge of the watch may operate the soot blowers himself, or he may supervise the messenger or the auxiliary man in this work. The checkman must NEVER be given this or any other duty to distract him from his job.

In blowing tubes, the steam lines to the soot blowers must first be warmed and drained. A drain hole in the soot blower valve allows constant drainage to the bilges while the soot blowers are in operation. Tubes must be blown in the proper sequence. Soot blowers should be used at least once a watch while under way, twice a day during in-port steaming, and just prior to securing a boiler. On controlled superheat boilers, tubes must NEVER be blown on the superheater side unless the superheater side is lighted off. When blowing tubes, the forced draft blower speed must be increased sufficiently so that all soot will be blown from the furnace and out the stack.

In order to perform his duties, the man in charge of the watch must know the correct procedures to be followed in lighting off, operating, and securing boilers; the methods of lining up, starting, operating, and securing all fireroom machinery; the correct procedure for keeping fireroom logs and records; the location of all machinery, lines, manifolds, valves, and other parts of the installation; the use of all firefighting equipment; and all fireroom safety precautions and casualty procedures.

Checkman

As checkman, you are responsible for operating the feed stop valve and the feed check valve. The stop valve is kept fully opened at all times while the boiler is steaming, and

the check valve is used to regulate the amount of water admitted to the boiler. Normally, the water level of a steaming boiler is kept at the middle of the 10-inch water gage glass.

The checkman has ONLY ONE JOB: maintaining the proper water level in the boiler. This job requires full attention at all times. Most high-water and low-water casualties are caused by inattention on the part of the checkman.

The feed pressure must be somewhat above boiler pressure in order to allow the feed water to enter the boiler. As a rule, feed pressure is maintained about 75 to 150 psi above steam drum pressure. If you have trouble getting enough water to feed the boiler, you may have to call for higher feed pressure.

Adjustments of the water level should be made gradually, and only as necessary. Sudden fluctuations of water level caused by great variations in the rate of feeding are detrimental to boiler efficiency. During lighting off, securing, and maneuvering, the water level will, of course, not remain constant; but at all other times the water must be kept at steaming level.

As long as a boiler is furnishing steam, the feed supply should NEVER be shut off entirely, even for a short period. The reason for this is that water must be kept flowing through the economizer at all times. If the flow were entirely stopped, the economizer would become overheated to such an extent that the aluminum fins might be melted.

As checkman, your hardest job will probably be to learn to regulate the water to meet changing steam demands. As the firing rate is increased, the water level rises because of an increase in the number and size of the steam bubbles in the water. As the firing rate is decreased, the water level falls because there are fewer steam bubbles in the water, and they are of smaller size. Thus, the total volume varies with the rate of combustion.

When the firing rate is increased, however, the evaporation rate is also increased. When the firing rate is increased, therefore, the checkman must remember to feed MORE water

to the boiler, even though the water level has already risen momentarily. Conversely, when the firing rate is decreased, the checkman must feed LESS water to the boiler, even though the water level has already dropped.

Water gage glasses must be blown down before the boiler is connected to the steam line, at the end of each watch, and whenever you have any reason to suspect that they may not be registering the actual water level in the boiler. If the water in the gages does not fluctuate with the roll and pitch of the ship, for instance, you should blow down the gages.

When connecting a boiler to the steam line, the blowing down of the water gage glasses must be done in the presence of the PO in charge of the watch. At the end of a watch, the gages must be blown down in the presence of the man in charge of the watch coming on and the man in charge of the watch being relieved.

The procedure for blowing down a water gage glass is as follows:

1. Unhook the chains which connect the top and bottom valve handles.
2. Close the top cut-out valve, and open the drain at the bottom of the assembly. This will allow the water to flow through the bottom connection and clear out any obstructing matter such as dirt or scale.
3. Open the top cut-out valve and close the bottom cut-out valve. This will allow the steam to flow through the top connection and clear it of any obstructing material.
4. Close the drain valve.
5. Open the bottom cut-out valve. This will allow the water to enter the gage. Check the water level against the level shown on the other gage.
6. Hook the chains which connect the top and bottom valve handles.

After blowing down a water gage glass, be SURE that both the valves are opened wide and that the water level indicated is correct. If there is any delay or sluggishness in the return

of the water level to the glass, find out the cause of the trouble and correct it immediately.

When checking the water level in a glass, always be sure that the APPARENT water level is actually the TRUE water level. Sometimes, for example, a fine crack in the glass or a thin line of dirt may give a false impression of the water level.

If you detect any sign of oil on the surface of the water in the gage glass, report it immediately. Even a small amount of oil in the boiler water is a serious casualty requiring immediate correction.

Priming due to foaming may be indicated in the water gage glass by an excessive amount of condensate running down from the top connection, particularly if this occurs along with rapid, momentary high-water levels which have no other apparent cause. This condition should be reported immediately to the PO in charge of the watch.

As checkman, you must be thoroughly familiar with the automatic feed water regulator installed on your boiler. Single-element automatic regulators are installed primarily for the purpose of regulating the water level under battle conditions, where manual feeding of the boiler might become difficult or impossible. When general quarters is sounded, the single-element automatic regulators must be cut in immediately. They may also be used under normal cruising conditions. However, the use of single-element automatic regulators does NOT relieve the checkman of his duties. He must remain at his station and continue to perform his duties unless emergency conditions force him to leave. Multi-element regulators must be kept in use at all times. No checkman is stationed at the check valve when multi-element regulators are used.

If single-element automatic regulators are not used for normal steaming, they must be cut in and operated for a reasonable period each day, in order to ensure their proper operation under emergency conditions. The control elements for single-element regulators are mounted on the steam drum; these elements must be cut in at all times, and must

be blown down at regular intervals, as indicated in the manufacturers' instruction books.

As a rule, automatic feed water regulators vary the supply of feed water by actuating a feed-regulating valve in the feed line. This valve is usually installed in the main feed line, between the feed stop and check valves and the economizer. When the automatic regulator is in use, the stop and check valves must be fully open; when the automatic regulator is not in use, the feed-regulating valve must be fully open so that it cannot interfere with manual feeding of the boiler.

The checkman should notify the PO in charge of the watch IMMEDIATELY of any abnormal operating condition or of any condition beyond his control. Procedures for dealing with high-water and low-water casualties are discussed in the chapter on fireroom casualty control.

Blowerman

As blowerman, you are responsible for operating the forced draft blowers which supply air for combustion. Although the air pressure is affected by the number of registers in use and the extent to which each register is open, it is primarily determined by the manner in which the forced draft blowers are operated. The opening, setting, or adjustment of the air registers is the burnerman's job; the control of the forced draft blowers is the blowerman's job. It is very important that the burnerman and the blowerman work in close cooperation, since both are concerned with the combustion of the fuel.

As blowerman, you must furnish the amount of air which, after adjustment of the air registers, will be sufficient for proper combustion of the oil. Any increase in air pressure beyond this point will result in EXCESS AIR. Excess air is undesirable because it is wasteful of fuel. The air which is not needed for combustion merely absorbs and carries off heat, thus increasing the fuel requirements and decreasing the steaming radius of the ship. WHITE SMOKE is always an indication of a very large amount of excess air.

On the other hand, you must be sure to supply ENOUGH air for complete combustion of the fuel. Insufficient air pressure will cause panting and vibration of the boiler, and will result in HEAVY BLACK SMOKE.

In operating the blowers, therefore, you must keep the air pressure at the point which will allow the fuel oil to burn completely, without creating smoke; but you must at the same time be sure that you are using the MINIMUM amount of air pressure required for combustion. For the sake of economy, you may be instructed to carry a LIGHT BROWN HAZE; in this case, you supply slightly LESS air than would be required for smokeless operation.

Since the amount of air to be supplied by the forced draft blowers depends upon the rate of combustion, the blowerman must always know what the burnerman is about to do. Air pressure must be increased BEFORE the rate of combustion is increased, and decreased AFTER the rate of combustion is decreased.

As you supply air to the boiler, you will be building up the air pressure in the space between the inner and outer boiler casings. This pressure is registered on the AIR PRESSURE GAGE. You will have to learn by experience how much air pressure is required to maintain good combustion when varying numbers of burners, sizes of sprayer plates, and oil pressures are used.

The actual operation of the blowers is accomplished by adjusting the blower throttle. You should use the MINIMUM number of blowers required to produce the desired air pressure. Remember, it is always more economical to run one blower at full capacity than to run two blowers at partial capacity.

The blowerman must keep a constant check on furnace conditions. Most modern boilers have SMOKE PERISCOPES through which you can observe the smoke conditions in the uptake. When a daylight bulb is used in the smoke periscope, the smoke and air conditions are indicated in the following manner:

Appearance of light	*Smoke and air conditions*
White	No smoke; but may be considerable excess air.
Slightly dimmed or hazy	Slight haze; air supply about right for most economical operation.
Increasingly dark	Increasing amounts of black smoke; more air required.
Slightly dimmed, with red tinge	Small amount of white smoke; large amount of excess air.
Completely black	Large amount of either white or black smoke; too much or too little air.

If observation through the smoke periscope indicates improper combustion conditions, you should check the appearance of the flames through the furnace peepholes. When operating at low or moderate combustion rates, the color of the flame is an indication of the furnace efficiency. An incandescent white flame, through which the furnace walls are clearly visible, indicates a considerable amount of excess air. A yellowish-orange or golden color at the end of the flame farthest from the atomizers, through which the seams in the furnace walls are just barely visible, indicates a minimum of excess air.

At very high rates of combustion, when the flame completely fills the furnace, it is more difficult to identify good and bad combustion conditions. An incandescent and dazzling white flame still indicates excess air; but a reduction in this excess air merely lowers the intensity of the whiteness, and does not cause the flame to appear yellowish-orange.

A perfectly clear smokestack is often deceiving. It may mean that you are operating with only a very small amount of excess air, but it may also mean that you have as much

as 300 percent excess air. A clear stack is ideal when the flue gas analysis at the same time shows a high percentage of carbon dioxide, very little oxygen, and no carbon monoxide.

It should be noted that the presence of black smoke does not always indicate insufficient air. Smoke can be caused by poor atomization (due to faulty burners, low oil temperature, etc.), by poor mixture of air and oil, by unconsumed oil striking tubes or furnace walls, and by other factors. Defects of this type must be eliminated before proper oil and air regulation can be achieved.

Burnerman

The burnerman on an uncontrolled superheat boiler, or on the saturated side of a superheat control boiler, cuts burners in and out and adjusts the oil pressure in order to keep the steam pressure at the required point. He is guided by the steam drum pressure gage. In addition, he watches the annunciator, which shows the signals going from the bridge to the engineroom, and in this way he can tell what steam demands are going to be made.

The burnerman on the superheater side of a superheat control boiler cuts burners in and out and adjusts oil pressure in order to keep the superheater outlet temperature at the required point. The burnerman on the superheater side is guided by the distant-reading thermometer, which indicates the temperature of the steam at the superheater outlet. In addition, he must keep check on what the saturated-side burnerman is doing, so that he will always know how many burners are in use on the saturated side.

When two boilers are both furnishing steam to the same engine, the burnermen of both boilers must work together closely so that the load will be equally divided between the two boilers.

Under normal steaming conditions, the atomizer assemblies are kept in place in all burner openings, ready to be cut in when needed. It is important to remember that the same size sprayer plates must be used in all burners in any one

furnace. Standby atomizer assemblies are usually made up and stowed in racks near the boiler front. When changing atomizers, BE SURE to check for size and proper assembly.

To cut in a burner, push the distance piece in to the proper position and lock it in place. The distance piece must be pushed in far enough to prevent the oil from hitting the brickwork, but not so far that it will allow air to enter the furnace without mixing with the oil. The correct position of the distance piece must be determined with regard to the size of the sprayer plate in use and the number of burners in use. Distance pieces are usually marked so that you can tell how far in you are putting them.

When the distance piece is in place, check to be sure that the manifold valve is open. Open the air register to the proper position. Open the needle valve. You may have to flip the air register shut MOMENTARILY, to allow the flame from other burners to reach the oil from the burner you are cutting in.

After you have cut in a burner, look through the peephole to see that the burner is functioning properly. Check for proper atomization of the oil; be sure the flame is near the diffuser; and be sure that the cone of atomized oil is as near the burner opening as it can be without hitting the brickwork.

Keep a close check on the fuel oil temperature gage. Large changes in firing rate will require an increase or a decrease in the amount of steam going to the fuel oil heater.

Watch the steam pressure gage, and adjust the micrometer valve as required to maintain the proper oil pressure. Oil pressure should be maintained between 125 and 300 psi, depending upon steam demands. The lower pressure of 125 psi should not be used except to take care of temporary maneuvering conditions. When the larger sizes of sprayer plates are used, keep the oil pressure between 200 and 300 psi.

To cut out a burner, close the needle valve, close the air register, and retract the distance piece. If the burner is not to be used soon, the manifold valve should be closed. If the burner is not likely to be used for some time, the atomizer assembly should be entirely withdrawn, and should be properly cleaned.

Burners should be changed at least once each watch, and more often if necessary. Dirty burners should be disassembled and cleaned.

At least once each watch, punch through the drain holes with a metal rod to be sure that they are free of oil, carbon, or other material.

Burners must NEVER be lighted on the superheater side until an adequate steam flow has been established through the superheater. Burners must NEVER be lighted on the superheater side unless one or more burners are in operation on the saturated side. When only the saturated side is in use, the air doors on the superheater side must be kept tightly closed in order to prevent air leakage through the superheater.

The burnerman on the superheater side must know and follow the prescribed rate for raising and lowering superheat temperature. As a rule, the rate of increase or decrease of superheat temperature should be about 50° F every five minutes. Superheat temperature must be lowered when the astern engine is being used. Even when lowering superheat temperature for reversing, however, you should follow the prescribed rate of decrease.

When the superheater temperature alarm sounds, you must cut down the firing rate until the temperature is brought back to normal. However, do NOT secure all burners on the superheater side as long as there is an adequate steam flow through the superheater.

Fireroom Auxiliaries

The number of men assigned to operate fireroom auxiliary machinery varies from one ship to another, depending upon the size of the ship and the number of men available. Some ships will have one or two men assigned to this duty, while in other ships the work may have to be done by the PO in charge of the watch or by the messenger.

If you are assigned to take care of the auxiliary machinery, you will have to line up, start, operate, and secure the main and emergency feed pumps, the fuel oil service pumps, the fire and bilge pump, the forced draft blowers, and—on some ships—the cooling water service pumps.

Operating instructions are posted beside each auxiliary unit. General instructions for operating pumps, blowers, and the auxiliary turbines which drive them are given in chapters 5, 6, and 7 of this training course.

Almost every fireroom pump has a standby pump which can be cut in immediately in the event of failure of the one in use. It is your responsibility to see that all standby pumps are in readiness at all times. It is considered good practice to have the emergency feed pump actually operating slowly at all times while under way, especially when operating at high speeds. If main feed pressure is lost, you can immediately start feeding the boilers with the emergency feed pump.

Cooling water for auxiliary machinery is generally furnished by a cooling water pump. If this pump fails, cooling water may be obtained from a standby cooling water pump or, through reducing valves, from the firemain.

Auxiliary machinery must have an adequate supply of clean lubricating oil at all times. Oil coolers should be cut in as soon as the lube oil temperature has risen to its normal operating value, and should remain in service as long as the unit is in operation.

If you are in charge of operating the auxiliary machinery, you must keep a constant check on all pressure and temperature gages. These gages are your best indication of how the machinery is operating. Pressure and temperature gage readings on all auxiliary machinery must be taken at frequent intervals, and must be entered in the log once an hour.

IN-PORT STEAMING

As a Third Class or Second Class Boilerman, you may be required to take charge of a fireroom watch in port, under auxiliary steaming conditions. Although the rate of steam generation is lower for in-port steaming than it is while the ship is under way, the procedures to be followed and the precautions to be observed are essentially the same for both conditions.

In uncontrolled superheat boilers, all steam generated is

passed through the superheater tubes. Thus, the superheater is protected at low steaming rates, as well as at higher rates, by always having a flow of steam through the tubes. However, the superheater on a two-furnace, single-uptake, superheat control boiler requires special protection at low steaming rates. As a general rule, lower superheater outlet temperatures are carried for in-port steaming than for under-way steaming. You should follow the ship's operating instructions closely, being particularly careful to avoid excessive temperatures.

Soot deposits tend to accumulate rapidly on economizer tubes, particularly at low firing rates. If the soot catches fire, the aluminum fins on the economizer are likely to be melted. Particular care must be taken during low-rate steaming to keep the economizer free of soot. When blowing tubes, be sure to blow the soot from the economizer.

Care must also be taken, in port as under way, to ensure an adequate supply of water to the economizer at all times. As long as a boiler is furnishing steam, the feed supply must NEVER be entirely shut off, even for a short time.

SECURING BOILERS

The following instructions for securing boilers apply to all modern express boilers. Special additional instructions for securing superheaters are given after the general procedure has been indicated. The information given here must, of course, be supplemented by specific operating instructions issued by the Engineer Officer and by the manufacturer of the equipment.

In general, these are the steps to be followed in securing a boiler:

1. Blow tubes, after permission has been obtained.
2. Close the atomizer valves, one at a time, and at the same time close the air registers.
3. Slow down the fuel oil service pump, as the burners are being secured.
4. Secure the steam to the fuel oil heater.

5. When all burners have been secured, stop the fuel oil service pump.
6. Slow the forced draft blowers, but continue to run them until the furnace has been cleared of all gases of combustion.
7. Open the fuel oil recirculating valves, and leave the fuel oil system lined up as though for recirculation, until the fuel oil heaters have cooled. This procedure will allow the hot oil in the heaters to expand without lifting the relief valves.
8. Remove the atomizer assemblies, and clean them as soon as possible.
9. Close up the furnace tightly, to keep cool air from flowing into the hot furnace. Sudden cooling causes serious damage to furnace refractories and to tubes.
10. When the boiler has cooled enough so that it is no longer generating steam, close the boiler steam stops and fill the boiler to the three-fourths level in the water gage glass.
11. Secure the feed pump and the feed system, when feed water is no longer needed. CAUTION: Do NOT secure the feed system while the boiler is still generating steam!
12. Clean out the accumulated oil in all drip pans, and wipe down all machinery and floor plates. Clean out any oil accumulations in the bottoms of air casings, and wipe down any drips on the inner fronts of air-encased boilers.
13. When all fires are out in the boilers leading to one stack, and when the stack has cooled sufficiently, put on the stack cover.

SPECIAL INSTRUCTIONS FOR SECURING BOILERS WITH UNCONTROLLED SUPERHEATERS include opening the superheater protection exhaust valve BEFORE the steam flow through the superheater has stopped. Keep this valve open until the steam drum pressure has dropped to 100 psi or less.

SPECIAL INSTRUCTIONS FOR SECURING SUPERHEAT CONTROL BOILERS include:

1. Drop the superheat temperature to about 600° F at the rate of about 50° F every five minutes.
2. Secure the superheater fires.
3. Secure the saturated-side fires.
4. Close the boiler steam stop valves.
5. Bleed the superheater until the boiler has ceased generating steam.

FIREROOM LOGS AND CHECK-OFF LISTS

The fireroom operating record—or log, as it is usually called—is filled out by operating personnel in the fireroom. Entries must be made regularly and accurately, once every hour.

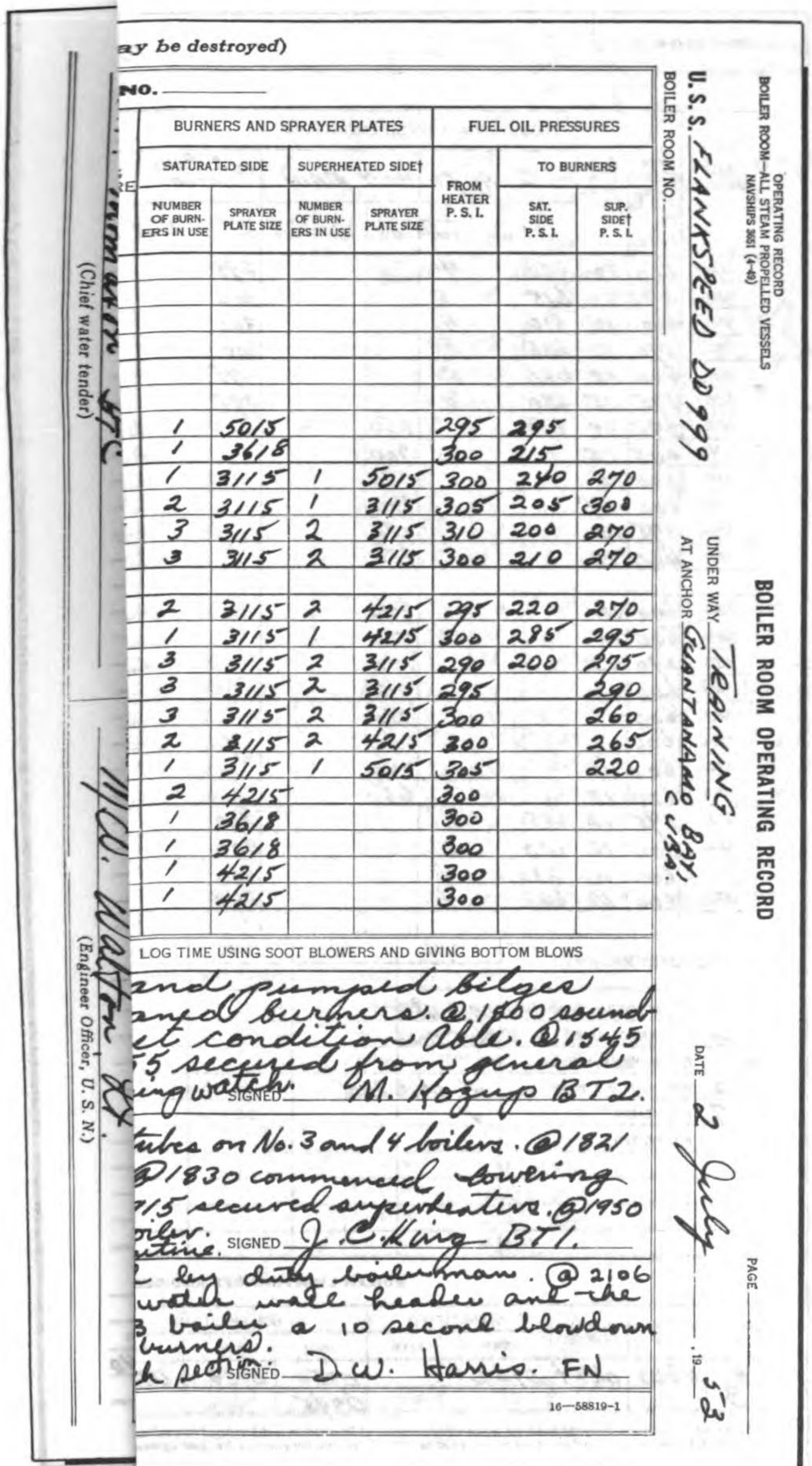
The boiler (front) side of the fireroom log contains space for such items of information as steam drum pressure, superheated steam pressure and temperature, desuperheated steam pressure, economizer inlet and outlet temperatures, air casing pressure, number of burners and sizes of sprayer plates, and fuel oil pressures. Figure 11–1 shows the boiler side of a fireroom log.

The auxiliary machinery (back) side of the fireroom log contains space for entries on fireroom auxiliary machinery such as feed system pumps, fuel oil pumps, fuel oil heaters, fuel oil meters, and forced draft blowers. Figure 11–2 shows the auxiliary machinery side of a fireroom log.

Check-off lists are used throughout the engineering plant, as a means of ensuring the accomplishment of all steps necessary for machinery operation. No matter how familiar you are with fireroom lighting off and securing procedures, you must ALWAYS use the check-off lists. You must fill them out in the proper manner, and sign them before going off watch.

FIREROOM SAFETY PRECAUTIONS

The importance of fireroom safety precautions cannot be overemphasized. As a petty officer, you must be entirely familiar with the precautions to be observed in operating boilers and all fireroom auxiliary machinery; and you must



BOILER ROOM—ALL STEAM PROPELLED VESSELS OPERATING RECORD
NAVSHIPS 3651 (4-48)

U.S.S. FLANKSPEED DD 999

BOILER ROOM NO. ____

BOILER ROOM OPERATING RECORD

UNDER WAY Training
AT ANCHOR Guantanamo Bay, Cuba.

DATE 2 July, 19 53

PAGE ____

...ay be destroyed)

NO. ____

BURNERS AND SPRAYER PLATES				FUEL OIL PRESSURES		
SATURATED SIDE		SUPERHEATED SIDE†		FROM HEATER P. S. I.	TO BURNERS	
NUMBER OF BURNERS IN USE	SPRAYER PLATE SIZE	NUMBER OF BURNERS IN USE	SPRAYER PLATE SIZE		SAT. SIDE P. S. I.	SUP. SIDE† P. S. I.
1	5015			295	295	
1	3618			300	215	
1	3115	1	5015	300	240	270
2	3115	1	3115	305	205	300
3	3115	2	3115	310	200	270
3	3115	2	3115	300	210	270
2	3115	2	4215	295	220	270
1	3115	1	4215	300	285	295
3	3115	2	3115	290	200	275
3	3115	2	3115	295		290
3	3115	2	3115	300		260
2	3115	2	4215	300		265
1	3115	1	5015	305		220
2	4215			300		
1	3618			300		
1	3618			300		
1	4215			300		
1	4215			300		

LOG TIME USING SOOT BLOWERS AND GIVING BOTTOM BLOWS

...and pumped bilges
...aned burners. @1500 sound
...t condition Able. @1545
...5 secured from general
...ing watch. SIGNED M. Kozup BT2.

...tubes on No. 3 and 4 boilers. @1821
...@1830 commenced lowering
...715 secured superheaters. @1950
...oiler.
...utine. SIGNED J. C. King BT1.

... by duty boilerman. @ 2106
... water wall header and the
...3 boiler a 10 second blowdown
... burners.
...h section. SIGNED D. W. Harris. FN

16—58819-1

...mmerer BTC
(Chief water tender)

M. W. Walton Lt.
(Engineer Officer, U. S. N.)

...ecord (boiler side).

may be destroyed)

BLOWERS										S. W. SERVICE	
NO. 6		NO. 7		NO. 8		NO.		NO.		F & F OR F & B DISCH. PRESS.‡	MACH. UNIT COOLING DISCH. PRESS.
R. P. M.	LUB. TEMP.	R. P. M.	LUB. TEMP.	R. P. M.	LUB. TEMP.	R. P. M.	LUB. TEMP.	R. P. M.	LUB. TEMP.		
										95	26
										90	24
										95	25
										98	25
										100	24
1500	120									95	22
1300	126									98	24
1500	128	1550	125	1500	124					100	25
2650	124	2500	128	2550	126					95	22
3500	126	3450	126	3500	128					100	24
4300	130	4300	130	4350	128					90	20
4250	128	4250	128	4300	130					100	25
3850	130	3950	132	3800	130					100	24
3050	130	2950	130	3000	130					95	25
4400	126	4300	128	4350	126					90	22
4400	132	4500	130	4550	128					100	22
4250	130	4250	130	4300	130					100	25
3800	130	3700	128	3750	132					100	25
2600	132	2450	130	2500	132					95	22
				2250	130					100	24
				2000	126					100	24
				1850	124					100	25
				1800	124					100	25
				1800	126					100	25

TOTAL HR.—MIN.	AUXILIARY MACHINERY	*TIME START	*TIME STOP	*TIME START	*TIME STOP	*TIME START	*TIME STOP	*TIME START	*TIME STOP	TOTAL HR.—MIN.
3-36	†									
-40	†									
2-28	NO. PRESS. COMPRESSOR									
	†									
	NO. 3 F & B PUMP	0945	1005							20
	NO. F & F PUMP									
9-42	NO. UNIT COOLING PUMP									
4-08	†									
1-51	†									
6-06	†									

SPECIAL FUEL OIL METER READING

	CUT OUT		FIRST BELL		LAST BELL	
…ADING	TIME	METER READING	TIME	METER READING	TIME	METER READING
710			0803	232,800	1935	240,390
	1950	240,450	—	—	—	—

Write Legibly—Keep Record Clean

16—58819-1 U. S. GOVERNMENT PRINTING OFFICE

…om operating record (auxiliaries side).

be constantly alert to prevent any violation of these precautions.

Safety precautions for various auxiliary units have been discussed in the appropriate chapters throughout this training course. A few of the most essential safety precautions pertaining to boilers are given below. However, these must be supplemented by a very thorough study of the safety precautions prescribed by the Engineer Officer on your own ship.

The following precautions must be observed PRIOR TO PLACING A BOILER IN SERVICE:

1. Make all prescribed tests of safety valves.
2. Test all automatic safety devices to make sure that they are operating properly.
3. In lighting off, run the water just out of sight in the bottom of the water gage glass. Then use the emergency feed pump to bring the water up to about 1 inch in the glass.
4. Always blow through the furnace with air or steam before lighting off. Always blow through the furnace before relighting burners, when all atomizers have been extinguished.
5. On or before lighting the first burner in a boiler with uncontrolled superheat, open the superheater protection exhaust valve and the superheater protection steam inlet valve, to establish a positive flow of steam through the superheater.
6. Never light a burner on the superheater side of a superheat control boiler until one or more burners are in operation on the saturated side. NEVER LIGHT A BURNER ON THE SUPERHEATER SIDE UNTIL YOU ARE SURE THAT A POSITIVE STEAM FLOW HAS BEEN ESTABLISHED THROUGH THE SUPERHEATER.

The following precautions must be observed WHILE THE BOILER IS BEING OPERATED:

1. Do not exceed the authorized maximum steam drum pressure.
2. Do not leave disconnected atomizers in place.

3. At least once each hour, test the drains from the fuel oil heater.
4. As long as a boiler is furnishing steam, do NOT shut off the feed supply even for a short time.
5. Blow through water gage glasses before the boiler is cut in on the steam line; at the end of each watch; and whenever there is any question as to the water level in the steam drum.
6. Observe the following precautions to reduce the danger of flarebacks:
   a. Do not allow oil to accumulate in furnaces. Keep atomizer valves tight.
   b. If burners are suddenly extinguished, shut off the oil supply and blow through the furnace with steam or air.
   c. Never attempt to relight burners from hot brick work.
   d. ALWAYS USE A TORCH TO LIGHT OFF THE FIRST BURNER. ALWAYS USE A TORCH TO LIGHT OFF ADDITIONAL BURNERS UNTIL THE FURNACE HAS BECOME VERY HOT!
   e. When lighting off a burner, stand clear to avoid injury from a flareback.
7. Never blow down the division wall headers, the water screen headers, or the water wall headers of a boiler until after all burners have been secured.
8. When securing a boiler with uncontrolled superheat, open the discharge connection to the auxiliary exhaust BEFORE the steam flow through the superheater has stopped. Keep this connection open until the steam drum pressure has dropped to 100 psi or less.
9. When securing a superheat control boiler, drop the superheat temperature SLOWLY—about 50° F every five minutes. Always secure the burners on the superheater side BEFORE securing those on the saturated side.

The following precautions must be observed AFTER THE BOILER HAS BEEN SECURED:

1. Remove atomizer assemblies as soon as possible after securing.

2. Close all openings to the furnace after all burners have been extinguished.
3. After the boiler has ceased generating steam, fill the boiler to the three-fourths level in the water gage glass and close the feed check and stop valves and the steam stop valves.
4. Before removing any fittings or parts subject to pressure, and before loosening a manhole or handhole plate fitting, take steps to ensure the complete absence of pressure. Open the air cock and the superheater vents, and test the blowdown from the upper water gage cut-out valve.

QUIZ

1. Why is it necessary to inspect all atomizer assemblies, before you insert them in the burners?
2. Why should the emergency feed pump be used during the lighting off period?
3. At what point in the lighting off period should you test the main feed pump?
4. When lighting off a boiler, how far should the boiler be pumped down?
5. During the lighting off period, what should you do to make sure that the main steam stop valve will not stick when it is heated?
6. If the fuel oil is so cold and viscous that the service pump has difficulty taking suction during the lighting off period, what should you do to overcome this difficulty?
7. What type of sprayer plate should be used for lighting off?
8. In lighting off a boiler, when should you close the steam drum aircock and superheater vents?
9. In lighting off a boiler, when should you lift safety valves by hand?
10. Should a boiler be cut in on the main steam line before or after it it cut in on the auxiliary steam line?
11. When lighting off a boiler with uncontrolled superheat, why should you open the superheater protection exhaust valve and the superheater protection steam inlet valve?
12. What must be done before burners may be lighted on the superheater side of a superheat control boiler?
13. When only the saturated side of a superheat control boiler is lighted off, what is the proper position for the air registers on the superheater side?
14. Why must the feed supply NEVER be shut off entirely, even for a short time, to any boiler that is furnishing steam?
15. How often must water gage glasses be blown down?
16. What combustion condition is indicated by white smoke?
17. How does the burnerman regulate the fuel oil pressure?
18. What is the usual allowable rate of increase or decrease of superheat temperature?
19. In securing a boiler with uncontrolled superheat, when should you open the superheater protection exhaust valve? How long should you leave this valve open?

CHAPTER 12.

FIREROOM CASUALTY CONTROL

The purpose of engineering casualty control is to prevent, minimize, and correct the effects of operational or battle damage to the ship's engineering plant, so that all engineering services may be maintained in a maximum state of reliability under all conditions of operation.

For the Boilerman, engineering casualty control begins in the fireroom. If the boilers are unable to furnish steam, the ship will be unable to function as a fighting unit. Propulsion, gunnery, lighting, heating, ventilation, steering, and a variety of other essential services are dependent upon steam. It is your responsibility, therefore, to have such a thorough knowledge of the procedures for handling fireroom casualties that you will be able to act IMMEDIATELY, in the event of casualty to the boilers, the fireroom auxiliary machinery, or the associated systems of piping.

In this chapter we will consider the procedures for handling some of the most common fireroom casualties. The various casualties are discussed separately, but it is important to remember that casualties tend to be cumulative in effect. One thing leads rapidly to another. Loss of fuel oil suction, for example, will require that the burners be secured. When the burners are out, you lose auxiliary steam and electric power, and so cannot operate either steam-driven or electrically-driven auxiliaries. Without auxiliaries, you cannot supply air to the furnace or feed water to the boiler.

Thus any casualty may lead to others even more serious. Prompt action must be taken to control even minor casualties, in order to avoid a sequence of trouble which could lead ultimately to the total failure of the engineering plant.

In order to take prompt, corrective action in any emergency, you must be entirely familiar with the location of all valves in the systems. The cut-out valves which are installed in all major piping systems serve two essential purposes: (1) they allow segregation of the system for split-plant operation, and (2) they allow the isolation of damaged portions of the engineering plant—machinery units, compartments, and sections of line. As a Boilerman, you are required to know the location of the principal isolation valves in the engineering spaces and in adjacent spaces. You can acquire this information by studying the engineering piping system diagrams, and by making a sketch of each system, noting particularly the location of each cut-out valve.

To avoid confusion and to eliminate the possibility of error when setting up for split-plant operation, when cross-connecting, or when isolating damaged sections, all important valves in each engineering piping system are given identification numbers. The valves are marked in the following manner:

Main steam	MS1, MS2, MS3, etc.
Auxiliary steam	AS1, AS2, AS3, etc.
Main feed	MF1, MF2, MF3, MF4, etc.
Main condensate	MC1, MC2, MC3, etc.
Fuel oil	FO1, FO2, etc.

Other systems are similarly marked. With the valves marked in this fashion, the officer of the watch can order a fireroom or an engineroom to open or close any particular valve without taking time to describe its actual location. All engineering personnel must know both the physical location and the identification number of each valve.

The information on engineering casualty control which is given in this chapter is intended to give you a general idea of the methods of handling casualties, and to give some explanation of the reasons for certain procedures. . You must,

however, be thoroughly familiar with the methods of casualty control prescribed by chapter 88, BuShips *Manual*, and by the Engineering Casualty Control Book on your own ship.

WATER LEVEL CASUALTIES

For normal steaming, the water level in the boiler should be kept at the middle of the 10-inch water gage glass (and at the middle of the 18-inch assembly, where this is installed). If the water goes out of sight at the bottom of the 18-inch assembly, you have a LOW-WATER CASUALTY. If it goes out of sight at the top of the 18-inch assembly, you have a HIGH-WATER CASUALTY.

It is usually very difficult to distinguish between a low-water casualty and a high-water casualty, by observation of the water gage glass. The glass looks much the same when empty as it does when full. Ordinarily, droplets of condensate forming and trickling down the inside of the glass indicate an empty glass, and the absence of condensate indicates a full glass. However, it is often difficult to tell whether or not condensate is present.

If there is ANY DOUBT WHATSOEVER regarding the location of the water level in the water gage glass, disappearance of the water level MUST BE TREATED AS A CASUALTY REQUIRING IMMEDIATE SECURING OF THE BOILER!

Low Water

Low water is one of the most serious and most frequent emergencies to arise in the fireroom. Low water may be caused by failure of the feed pumps, leaks in the feed discharge line, defective check valves, low water in the feed tank, or other defects.

However, the most frequent cause of low water is inattention on the part of the checkman and the PO in charge of the watch, or the diversion of their attention to other duties. Remember, the checkman should have ONLY ONE DUTY—that of maintaining the proper water level in the boiler.

Low water is extremely damaging to the boiler, and may

endanger the lives of fireroom personnel. When the furnace is hot and there is insufficient water to absorb the heat, the heating surfaces are likely to be distorted, the brickwork damaged, and the boiler casing warped by the excessive heat. In addition, serious steam and water leaks, and even explosion of the boiler, may occur as a result of low water.

If the water level goes below the lowest visible part of the water gage glass, or IF THE WATER LEVEL DISAPPEARS AND YOU DO NOT KNOW WHETHER IT IS HIGH OR LOW, the following action must be taken IMMEDIATELY:

1. Shut off the oil supply to all burners.
2. Close the feed check valve and the feed stop valve. CAUTION: You must NEVER feed water to a boiler in an attempt to restore the water level after a low-water casualty!
3. Notify the engineroom; open the cross-connection valves if so ordered.
4. Close boiler stop valves to the main, auxiliary, and turbogenerator steam lines.
5. Blow through the water gage glasses, to determine whether the water level is high or low.
6. When you are SURE that you have a low-water casualty, rather than a high-water casualty, lift the safety valves by hand and gradually relieve the boiler pressure. CAUTION: Safety valves must NEVER be lifted in the event of a high-water casualty!
7. Close the burner registers and, if practicable, secure the forced draft blowers.
8. Allow the boiler to cool slowly.

High Water

If the water level goes above the highest visible part of the water gage glass, the following action must be taken IMMEDIATELY:

1. Close the feed check valve and the feed stop valve.
2. Shut off the supply of oil to the burners.

3. Secure the forced draft blowers.
4. Notify the engineroom; open the cross-connection valves if so ordered.
5. Close the main, auxiliary, and turbogenerator steam stop valves.
6. Blow through the water gage glasses, to be SURE that this is actually a high-water casualty rather than a low-water casualty.
7. When you are SURE that you have a high-water casualty to deal with, use the surface blow valve to blow the boiler down until the water is at the proper level.
8. Light off the boiler and cut it in on the line again.

FEED PUMP CASUALTIES

Failure of the feed system pumps may have drastic consequences, if prompt corrective action is not taken. Associated casualties may include the loss or impairment of auxiliary steam pressure and electric power, with consequent loss of both steam-driven and electrically-driven auxiliaries.

Feed Booster Pump Failure

In many installations, the feed booster pumps are in the engineroom rather than in the fireroom. In such an installation, feed booster pump failure will be indicated in the fireroom by loss of main feed pump suction and by the sounding of the low-pressure feed alarm (if fitted). The casualty to the feed booster pump will be dealt with by the engineroom personnel, if the pump is in the engineroom; but it is up to the fireroom personnel to secure the main feed pump immediately, and to take the following steps to maintain a supply of feed water to the boiler:

1. Start the emergency feed pump on COLD SUCTION. (The emergency feed pump can take a HOT SUCTION from the booster pump, or a COLD SUCTION from the reserve feed tanks. In standby condition, this pump should always be lined up on a cold suction.)

2. Ring for more feed, or otherwise notify the engineroom that you require more booster pressure or more feed pressure.
3. If so ordered, open the main feed pump discharge cross-connection valve in your own space and take feed from this source.
4. Keep the engineroom informed of the feed system in use (main or auxiliary), so that the ship's speed can be held within the limits of boiler capacity.
5. If you are not able to maintain the proper water level in the boiler, secure the boiler in order to prevent a LOW-WATER CASUALTY.

Main Feed Pump Failure

If the main feed pump discharge pressure is too low, the first two things to be checked are (1) the feed booster pump discharge pressure, and (2) the feed stop and check valves on idle boilers. A failure of the feed booster pump will, of course, cause loss of suction and, therefore, loss of discharge pressure of the main feed pump. If the feed stop and check valves on idle boilers have accidentally been left open, the main feed pump discharge pressure may be low merely because you have been pumping water to an idle boiler, as well as to the steaming boiler.

Some of the most likely causes of actual failure of the main feed pump are (1) malfunction of the constant-pressure pump governor, (2) an air-bound or vapor-bound condition of the main feed pump, (3) faulty pump clearances, and (4) malfunction or improper setting of the speed-limiting governor.

Failure of the main feed pump calls for the following action:

1. Start the standby main feed pump.
2. If no standby pump is available, start the emergency feed pump. If the feed booster pump is working, line up the emergency feed pump to hot suction; otherwise, line it up to cold suction.

3. Notify the engineroom; open the feed cross-connection valves if so ordered.
4. Keep the engineroom informed of the feed system in use (main or auxiliary), so that the limits of the ship's speed may be estimated.
5. If the water level cannot be maintained in the boiler, carry out the LOW-WATER CASUALTY procedure.

After you have carried out as much as necessary of the above procedure, check the main feed pump carefully to determine the cause of failure. If the pump is air-bound, it should be vented. Check the constant-pressure pump governor and the speed-limiting governor as thoroughly as possible, and remedy any defects.

FUEL OIL SYSTEM CASUALTIES

Casualties to any part of the fuel oil system are serious, and must be remedied at once. Common casualties include (1) oil in the fuel oil heater drains, (2) water in the fuel oil, (3) loss of fuel oil suction, (4) failure of the fuel oil service pump, and (5) fuel oil leaks.

Oil in the Heater Drains

Oil leakage from the fuel oil heaters into the drains may cause oil contamination of the drain lines, the reserve feed tanks, the deaerating feed tank, and the feed system piping and pumps. The presence of oil in any part of the feed system is dangerous because of the possibility that the oil will eventually reach the boilers, where it will cause steaming difficulties and serious damage to the boilers.

Fuel oil heater drains must be inspected hourly for the presence of oil. If oil is found in the drains, the following action must be taken immediately:

1. Shift the drains to the bilges.
2. If more than one heater is in use at the time of the casualty, secure the defective heater immediately. If no other heater is already in use, cut in another heater before securing the one which is leaking.

3. Notify the engineroom.
4. When the drains are clear of oil, shift back to the drainage system.

Water in the Fuel Oil

The presence of any considerable amount of water in the fuel oil is indicated by sputtering of the atomizers. If this condition is not corrected immediately, choked atomizers, loss of fires, and flarebacks may result.

The steps to be taken are as follows:

1. Shift suction to another tank.
2. Discharge oil through the recirculating line to the contaminated oil settling tank (or overboard) until the fuel oil service line is free of water.
3. Watch the fires carefully. If the fires go out, SECURE THE BURNERS.
4. If the burners are secured, drain the contaminated oil from the line between the burner manifold and the atomizer. To do this, crack the atomizer valve and allow the oil to drain from an atomizer that has been disconnected. This procedure also gives you a sample of oil, from which you will be able to tell when the oil is free from water.
5. When relighting, it may be necessary to use a large size burner until the system is entirely free of water. The large burners are not so likely to be extinguished by water in the oil as are the small burners.

Loss of Fuel Oil Suction

Loss of fuel oil suction most frequently occurs as a result of the oil level dropping to the suction level in the fuel oil service tank. When this happens, a mixture of air and oil is pumped to the atomizers, and the atomizers at once begin to hiss. To remedy this condition, suction must be shifted immediately to another tank.

It is often difficult to distinguish between loss of fuel oil suction and water in the fuel oil. If water is present in

the oil, the fuel oil service pump is likely to be very noisy in operation and may increase in speed.

If fuel oil service pump suction is entirely lost, but steam is still available from other boilers, the following action should be taken:

1. Secure all burners.
2. Leave at least one register open on the superheater side and one on the saturated side, in order to expel any gases of combustion and to supply air for the combustion of oil which may have accumulated on the furnace floor. Also, leave the forced draft blowers running as fast as necessary to furnish an air pressure between the casings of approximately 2 inches of water.
3. Start the standby pump. (Be SURE that it is lined up to a standby service tank.)
4. Notify the engineroom.
5. Open the cross-connection valves, if so directed by the engineroom.
6. After all oil has been burned from the furnace floors, close the registers and slow down the forced draft blowers.
7. Check the fuel oil system to see if the trouble is being caused by water in the oil or by air in the piping. Take appropriate action to rid the system of water or air, if present.
8. Check to see if the fuel oil service pump is air-bound. If it is air-bound, it will have little or no discharge pressure and it will be exceedingly noisy in operation. If the pump is air-bound, open the priming cock and vent the system.
9. If the fuel oil service pump is air-bound to such an extent that suction cannot be regained even after the pump is vented, line up the booster pump discharge to the service pump suction.
10. When fuel oil suction is regained, notify the engineroom, light off again, and put the boiler back on the line.

If fuel oil suction is lost when only one boiler is in use, the procedure given above must be modified as follows:

1. Do NOT leave the forced draft blowers running after the burners have been secured.
2. If fuel oil suction has not been regained by the time the boiler steam pressure has dropped to 85 percent of the authorized operating pressure, close the boiler stop valves to the main, auxiliary, and turbogenerator steam lines.
3. As soon as the steam stop valves have been closed, close valves in the steam lines so that ALL available steam will go to the fuel oil service pumps when the steam stops are opened again.
4. When suction is restored, light off again with only one atomizer.

It should be emphasized that the loss of fuel oil suction is a serious casualty which may have disastrous consequences. Associated casualties may include loss of auxiliary steam and electric power, with consequent loss of all steam-driven and electrically-driven auxiliaries.

Fuel Oil Service Pump Failure

The failure of the fuel oil service pump causes the same progressive casualties which result from loss of fuel oil suction. If the fuel oil service pump fails, the following action should be taken:

1. Cut in the standby pump. If that also fails, cut in the port-and-cruising pump (if installed). As a last resort, use the hand-driven fuel oil service pump. Make every effort to maintain steam pressure until the difficulty can be located and corrected.
2. Notify the engineroom. State which fuel oil pump is being used, so that the ship's speed can be held within the limits of boiler capacity.
3. Open the cross-connection valves, if so directed.
4. Close the boiler steam stop valves, if service cannot be reestablished with any fuel oil service pump.

Major Fuel Oil Leaks

If a fuel oil service line is ruptured on the DISCHARGE side of the fuel oil service pump, the following action must be taken:

1. Secure the fuel oil service pump, the discharge valve, and the quick-closing valve.
2. Notify the engineroom.
3. Secure the boiler.

NOTE: It is possible to operate temporarily with a small oil leak on the discharge side of the fuel oil service pump. If this procedure is necessary, be sure to smother the spray of oil from the line, and catch the oil in a pan or bucket.

If a fuel oil service line is ruptured on the SUCTION side of the fuel oil service pump, the following action must be taken:

1. Secure the fuel oil service pump.
2. Notify the engineroom.
3. Secure the boiler.
4. Isolate the service suction line, and line up the booster pump discharge to the service pump suction.

If a fuel oil service tank should be so damaged as to be unusable, take the following action:

1. Shift the service suction to a standby tank.
2. If you are unable to get suction from the standby tank, line up the booster pump discharge to the service pump suction.

SUPERHEATER CASUALTIES

If the distant-reading superheater thermometer does not register a normal increase in temperature when the superheater is first lighted off, the trouble may be either lack of steam flow or failure of the distant-reading thermometer. Lack of steam flow must be considered as a possible cause even if the superheater steam flow indicator shows that there is a flow. If the thermometer does not register a normal increase in temperature, the following steps should be taken:

1. Secure all superheater burners.
2. Check to be sure that the superheater steam flow indicator is properly cut in.
3. Check the distant-reading thermometer against the direct-reading superheater thermometer. If the two thermometers have previously been working properly, and if they now agree, the chances are overwhelmingly against the trouble being in the distant-reading thermometer.
4. To find out if there is a flow of steam through the superheater, lift the superheater safety valves by hand for a SHORT blow. This will establish a positive steam flow past the thermometers. Then recheck the thermometers. If they still agree, but at a different temperature, there is no flow through the superheater. If there is no flow, the superheater steam flow indicator is not functioning properly and must be repaired.
5. If it is necessary to continue to operate the boiler without the flow indicator, take every precaution to ensure a positive flow of steam through the superheater.

When operating with superheat, it is essential to keep a constant check on the flow of steam through the superheater and on the superheater temperature. Any deviation from normal conditions must be corrected without delay.

It is important to remember that a casualty to some other part of the engineering plant may reduce or entirely stop the flow of steam through the superheater, and so cause a superheater casualty, unless appropriate action is taken to prevent damage. For example, a casualty to the main engines might call for a sudden, large reduction or even a complete stoppage of steam flow. Even if you secure the superheater burners, you may still need a steam flow to protect the superheater from the heat of the furnace. In this event, or whenever you need a greater flow than you can obtain by ordinary means, LIFT THE SUPERHEATER SAFETY VALVES BY HAND, TO ENSURE A POSITIVE FLOW OF STEAM THROUGH THE SUPERHEATER.

When the superheater thermal alarm sounds, the superheater fires must be immediately decreased to bring the temperature below alarm temperature. Do NOT decrease the temperature further than necessary. It is very seldom necessary to secure all superheater burners in order to bring the temperature down to the prescribed point.

PRESSURE PARTS CARRIED AWAY

When a boiler pressure part is carried away, escaping steam may cause serious injury to personnel and severe damage to the boiler. The following steps should be taken, insofar as the particular circumstances will allow, to control the casualty:

1. Shut off the supply of fuel oil to the burners.
2. Close the air registers and speed up the forced draft blowers, to force the steam up the stack and to prevent it from blowing out into the fireroom.
3. While the first two steps are being carried out, take the following action:
   a. Close the main, auxiliary, and turbogenerator steam stop valves.
   b. Notify the engineroom.
   c. Open the cross-connection valves, if so ordered.
4. Lift the safety valves by hand, to relieve the steam pressure.
5. Continue to feed water to the boiler until it has cooled. Open the auxiliary check valve and start the emergency feed pump. The main feed supply must be shut off, if other boilers are being fed from it. CAUTION: Do NOT continue to feed water to the boiler if the casualty was caused by low water, or if the steam leak is so large that the water level cannot be maintained in the gage glasses.
6. After the fires are out and the pressure has been reduced sufficiently so that there is no danger of steam blowing into the fireroom, stop the blowers. Close the boiler up tightly so that no air will be allowed to leak into the furnace. Allow the boiler to cool SLOWLY.

WATER GAGE GLASS CARRIED AWAY

When a water gage glass is carried away, the following action should be taken:

1. Close the top and bottom cut-out valves to the damaged glass.
2. Open the drain valve.
3. Replace the damaged glass.
4. Slowly open the bottom cut-out valve and then the top cut-out valve, and check for leakage. If there is no leakage, close the drain valve and check the water level by the level shown in the other gage.

FLAREBACKS

A flareback is likely to occur whenever the pressure in the furnace momentarily exceeds the air pressure in a closed fireroom, or the boiler air-casing pressure in an open fireroom. Flarebacks are caused by an inadequate air supply for the amount of oil being supplied, or by a delay in lighting the mixture of air and oil.

Situations which commonly lead to flarebacks include: (1) attempting to light off or to relight burners from hot brickwork; (2) gunfire or bombing which creates a partial vacuum at the blower intake, thus reducing the air pressure supplied by the blowers; (3) forced draft blower failure; (4) accumulation of unburned fuel oil or combustible gases in furnaces, tube banks, uptakes, or air casings; and (5) any event which first extinguishes the burners and then allows unburned fuel oil to spray out into the hot furnace. An example of this last situation might be a temporary interruption of the fuel supply which would cause the burners to go out; when the fuel oil supply returned to normal, the heat of the furnace might not be sufficient to relight the burners immediately. In a few seconds, however, the fuel oil sprayed into the furnace would be vaporized, and a flareback or even an explosion might result.

Under normal steaming conditions, an inadequate supply of air may cause a condition known as PANTING of the boiler.

This is really a series of small flarebacks. If the lack of air is not remedied, the condition may become worse and may lead to major flarebacks.

Major flarebacks which extinguish the fires or cause boiler damage require the following action:

1. Shut off the supply of oil to the burners.
2. Notify the engineroom.
3. Use fire-fighting equipment, as necessary.
4. Close the main steam stop valve.
5. Adjust the feed check valves or stop the feed pumps, as necessary, to prevent high water in the boiler.
6. Speed up the forced draft blowers, to clear the furnace of unburned oil and gases.
7. Open the auxiliary steam cross-connection valves, if necessary, to maintain auxiliary steam service.
8. Secure the auxiliary steam stop valve.
9. When conditions permit, inspect the boiler. If it is not damaged, follow the normal procedure for lighting off.

Minor flarebacks which do not extinguish the fires do not necessarily require that the above procedure be carried out. After any flareback, however, the boiler should be carefully examined for indication of damage.

The following PRECAUTIONS must be observed by all fireroom personnel, in order to minimize the possibility of flarebacks:

1. Never allow oil to accumulate in the furnace.
2. Whenever atomizers are accidentally extinguished, shut off the oil and blow through the furnace before relighting the atomizers.
3. NEVER ATTEMPT TO RELIGHT AN ATOMIZER FROM A HOT BRICK WALL!
4. When lighting a burner, STAND CLEAR TO AVOID INJURY IN CASE A FLAREBACK OCCURS.

FIRES

Any leakage or accumulation of oil constitutes a fire hazard. Since an oil fire can assume serious proportions in a

very short time, all fireroom personnel must be thoroughly trained in the methods of putting out this type of fire. The basic principles of fire fighting are given in *Fireman*, NavPers 10520–A, and in the *General Training Course for Petty Officers*, NavPers 10055.

Oil fires are Class B fires, and are best put out by some type of smothering or blanketing action. Foam, carbon dioxide, steam, and a combination of fog and foam are effective in smothering Class B fires. Firerooms are equipped with the standard fire-fighting equipment, including portable equipment, specified in chapter 93, BuShips *Manual*. In addition, permanently fitted steam smothering lines are usually provided in the fireroom bilges and inside the casings beneath the boilers (in air-encased boiler installations). You should make it your business to know the exact location of all fire-fighting equipment in your fireroom. Be sure you know how to use the equipment. Also, be sure that you know the exact location of the steam smothering system valves to the bilges and to the air casing. The steam smothering lines must be examined and tested by steam at least once a month.

In the event of a MAJOR FIRE IN THE FIREROOM which prevents boiler operation, the following action must be taken:

1. Shut off the fuel oil supply and stop all fuel oil pumps.
2. Secure the burners and close the registers.
3. Stop the forced draft blowers.
4. Secure the ventilation supply and exhaust fans, EXCEPT when it is necessary to leave them in operation in order to provide a means of escape for fireroom personnel. The decision as to whether or not to secure the fans must be made by the fire-fighting personnel.
5. Use the fire-extinguishing equipment provided.
6. Notify the engineroom, and open the cross-connection steam valves if so ordered.

For an OIL FIRE IN THE BILGES, the following action should be taken:

1. Shut off the fuel oil supply to the burners.
2. Stop the fuel oil pumps.

3. Use the fire-extinguishing equipment provided. However, use the steam smothering system ONLY if the fire cannot be controlled by other means. All personnel must be out of the fireroom, and all hatches, ventilators, and other openings must be closed, before the steam smothering system is used.

For an OIL FIRE IN THE DOUBLE CASINGS, the following action should be taken:

1. Shut off the fuel oil supply to the burners, and stop the fuel oil pumps.
2. Stop the forced draft blowers.
3. Use the casing steam smothering system to extinguish the fire. NOTE: The steam smothering system may be used in the casings without danger to fireroom personnel.

QUIZ

1. What is the purpose of engineering casualty control?
2. What two essential purposes are served by piping system cut-out valves?
3. What is the first step to take if the water goes out of sight in the boiler water gage glass?
4. In the event of high water in a boiler, what should be done to bring the water down to the proper level?
5. What is the first thing to be done by fireroom personnel, in the event that casualty to the feed booster pump in the engineroom causes loss of main feed pump suction?
6. If oil is found in the fuel oil heater drains, what action should be taken immediately?
7. Under what conditions will the distant-reading superheater thermometer fail to register a normal increase in temperature when the superheater is lighted off?
8. What action should be taken when the superheater thermal alarm sounds?
9. Under what circumstances should water NOT be fed to the boiler, when a pressure part has carried away?
10. If the pressure in the furnace exceeds the pressure in the fireroom or in the air casing, what is likely to occur?
11. What is the most common cause of panting in a boiler?
12. How often should fireroom steam smothering lines be examined and tested?
13. What is the first thing to be done in the event of an oil fire in the bilges?
14. What fire-fighting equipment should be used to extinguish a fire in the casings of an air-encased boiler?

CHAPTER 13

BOILER MAINTENANCE AND REPAIR

As a Boilerman, you are responsible for much of the maintenance and repair work which is required to keep the boilers and the fireroom auxiliary machinery in good operating condition.

In this chapter, we will take up some of the most important aspects of boiler maintenance and repair: maintenance of boiler firesides, refractories, watersides, manholes and handholes, sliding feet, casings, water gage glasses, and soot blowers. In addition, some mention will be made of maintenance factors which are common to all fireroom auxiliaries.

You will find that a knowledge of blueprint reading is basic to most repair work. For general information on the use of blueprints, you should study *Blueprint Reading*, NavPers 10077. On board ship, blueprints and drawings pertaining to every piece of equipment in the engineering spaces are kept in the engineering log room. Before undertaking any major repair job, you should always consult these drawings.

MAINTENANCE OF BOILER FIRESIDES

Boiler firesides must be kept clean. Deposits of soot, slag, or carbon must not be allowed to develop, since they reduce heat transfer, contribute to corrosion, block the flow of combustion gases, and constitute a serious fire hazard. It is important to remember that dirty tubes accumulate soot at

a faster rate than clean tubes do. Keeping the firesides clean, therefore, actually saves maintenance work; it also helps to maintain boiler effiicency and prolongs the life of the boiler.

Soot should be blown from the tubes, by means of the soot blowers, at least once a watch while under way, twice a day during in-port steaming, and just prior to securing a boiler. If tubes are not blown often enough, soot will accumulate between the tubes, on top of the lower drums or headers. This soot will absorb moisture from the air, and in a short time may pack into such a solid mass that it cannot be removed by the blowers. In addition, moisture combined with soot forms sulphuric acid, which will corrode the tubes.

Soot and carbon accumulate to some extent, even when soot blowers are used routinely. For this reason, the boiler firesides must be cleaned manually at regular intervals. Cleaning of the firesides is mandatory after 600 hours of steaming; but in most cases it is not considered good engineering practice to wait this long between cleanings. As a general rule, the furnace should be entered after each steaming period at sea, and the firesides cleaned as necessary to prevent the accumulation of deposits.

Methods of Cleaning Firesides

The three methods commonly used to clean boiler firesides are: (1) wire-brush or scraper cleaning, (2) hot-water washing, and (3) wet steam lancing. In addition, a "sweating" method is sometimes used to clean superheater firesides.

WIRE BRUSHES and SCRAPERS must be used carefully so that the tubes will not be damaged. Special tools for reaching into the tube banks may be made up on board ship from sheet-metal strips, rods, or other material. After the soot and carbon have been loosened, air lances are usually used to blow it out of the tube banks.

When wire brushes and scrapers will not remove the deposits, the HOT-WATER WASHING method may be used. This method is particularly good for cleaning superheaters, economizers, and other parts of the boiler which are difficult to

reach. It should be used with caution, however, since any type of water washing offers some risk of damage to the brickwork and the boiler casing. Instructions for hot-water washing are given in chapter 51, BuShips *Manual*, and must be carefully followed.

Water may be applied locally, with water lances, or it may be distributed throughout the tube banks by the soot blowers. The first method requires less water, and does not wet the boiler and the refractories as much; the second method causes the water to reach all parts of the tube banks, but it requires a great deal more water and it results in considerable wetting of the boiler. The two water-washing methods may be combined, and good results are usually obtained in this way.

Boilers must be very thoroughly DRIED OUT after water washing, in order to prevent extensive damage to the boiler and the refractories. Immediately after water washing is completed, all water must be drained from the boiler firesides. Scale deposits should be removed from drums, casing corners, and refractories. The boiler should be closed up and lighted off. Use the smallest available sprayer plate and 200 psi oil pressure. Every 15 minutes the boiler should be secured for 15 minutes, to allow the moisture on the refractories to evaporate slowly. The burners should be used in rotation. The alternate firing and idle periods should be continued for about 5 hours. The boiler should then stand idle and be allowed to air-dry for an hour, after which time it should be lighted off and steamed to an auxiliary load.

If a boiler is to remain idle for some time after it has been dried out, it should be sprayed with metal conditioning compound.

WET STEAM LANCING is sometimes used to remove deposits from boiler firesides. A loop or coil in the steam supply line is inserted in a large container of water, and the steam is thereby cooled and condensed until it contains the required amount of moisture. The moisture in the steam tends to dissolve and loosen the deposits, which can then be removed by the scouring action of the steam.

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The SWEATING method is sometimes used to clean superheater tubes that are caked with heavy deposits of soot. In this method, very cold water is circulated through the superheater. When the superheater is cold, moisture from the warmer air condenses on it; and this moisture tends to dissolve the deposits sufficiently to permit removal by air lance or steam lance.

Metal Conditioning Compound

Metal conditioning compound is used to prevent rust and corrosion on boiler firesides, after a boiler has been water washed and thoroughly dried out. It may also be used as an aid in cleaning boiler firesides, particularly if there are heavy deposits of hard carbon on the tubes.

About one to three weeks are required for cleaning firesides when the metal conditioning compound is used. Therefore, this method can be used only when the operating schedule of the ship is such as to allow the boiler to be laid up for this period of time.

Before applying the metal conditioning compound, you must remove all loose dust, dirt, and soot. Then spray the fireside surfaces of the tubes and drums with the metal conditioning compound, using about 15 to 25 gallons of compound for each boiler.

After the compound has been allowed to take effect for a period of one to three weeks, the boiler should be lighted off and tubes blown. As soon as practicable, the boiler should be secured and the firesides should be cleaned to dispose of any accumulations not removed by the soot blowers. In most cases, any material remaining on the tubes or drums will be soft and easy to remove.

Metal conditioning compound is flammable and explosive under certain conditions. In addition, it has a sharp, pungent odor that may cause extreme discomfort to personnel. In general, the following precautions should be observed in the use of metal conditioning compound:

1. Be sure the fireroom is well-ventilated while the compound is being applied.
2. Wear a respirator and goggles.
3. Do not allow smoking in the fireroom.
4. Do not allow naked lights to be used in the fireroom.
5. Do not apply metal conditioning compound to a boiler while another boiler in the same compartment is steaming.
6. Do not apply the compound to a boiler which is connected to the same smokestack as a steaming boiler, unless division plates are installed to the top of the stack to prevent the mixture of the gases from the two boilers.
7. Do not use excessive amounts of the compound—use only as much as is necessary for the proper cleaning of the firesides.
8. When the boiler is initially lighted off after the compound has been applied, be particularly alert to detect fires which may occur as the result of the compound soaking into the insulation.
9. Do not enter the boiler during the period between the application of the compound and the steaming of the boiler, except to perform emergency work.

MAINTENANCE OF BOILER REFRACTORIES

Under normal operating conditions, the boiler furnance refractories should last for many years without requiring complete renewal. In order to maintain the refractories in good condition, however, the furnace must be kept clean and free of soot or carbon deposits, and all refractory defects must be promptly repaired.

The types of refractory materials used in naval boilers are described in chapter 2. It is important for you to know what types of refractories are used in each part of the furnace. When furnace brickwork is to be patched or partially replaced, you must ALWAYS use the type of refractory material specified for the area being repaired.

As a matter of routine maintenance, you will probably be required to replace small areas in the furnace floor or walls. PLASTIC FIREBRICK is usually used for this purpose; it is particularly useful because it can be pounded into spaces which would otherwise require firebrick of special or unusual shape. Plastic firebrick is almost equal to standard firebrick in refractory qualities, but it is not quite as strong and is subject to shrinkage after installation.

When patching a small area of wall with plastic refractory, you must first cut out all loose portions of brick and clean the area thoroughly. The firebrick must then be undercut, as shown in figure 13–1, and the plastic firebrick rammed in tightly and vented. The undercutting of the firebrick is necessary in order to keep the plastic firebrick patch in place.

A hand rammer for pounding plastic firebrick may be made up on board ship. The ramming end is made of steel plate. The shaft or handle is a piece of 7/8-inch or 1-inch cold-rolled

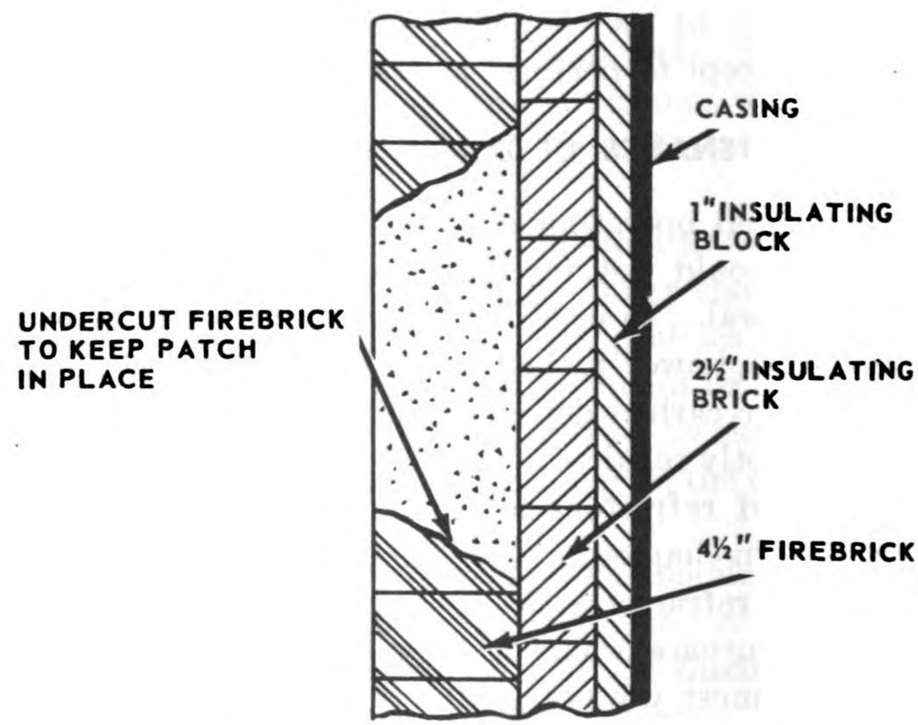


Figure 13–1.—Installation of a plastic firebrick patch.

steel rod about 18 inches long. A piece of cast iron, brass, or steel, shaped to fit the palm of the hand, may be welded to the end of the handle.

A ramming plate which can be attached to a pneumatic hammer is shown in figure 13–2. Like the hand rammer, this tool may also be made up on board ship. The ramming plate can be made of boiler plate about ½ to ¾ inch thick. Two sizes of rammers are usually kept on hand, the smaller size being about 3½ inches square and the larger size about 5 inches square. A piece of cold-rolled steel about 1 inch in diameter and 4 inches long is drilled out with a ⅝-inch drill to form a hollow adapter to fit the shank. The adapter is welded to the ramming plate. The shank can be made up from a regular pneumatic tool blank, or from a discarded chisel or calking tool. The shank must fit loosely in the adapter; do not attempt to weld it or otherwise fasten it firmly in place.

Another tool required for plastic firebrick work is a VENTING ROD. This tool is used to vent the plastic firebrick after installation. The tool consists of a 3/16-inch round steel rod about 14 inches long. One end of the rod is tapered to form a sharp point; the opposite end is fitted with a wooden handle.

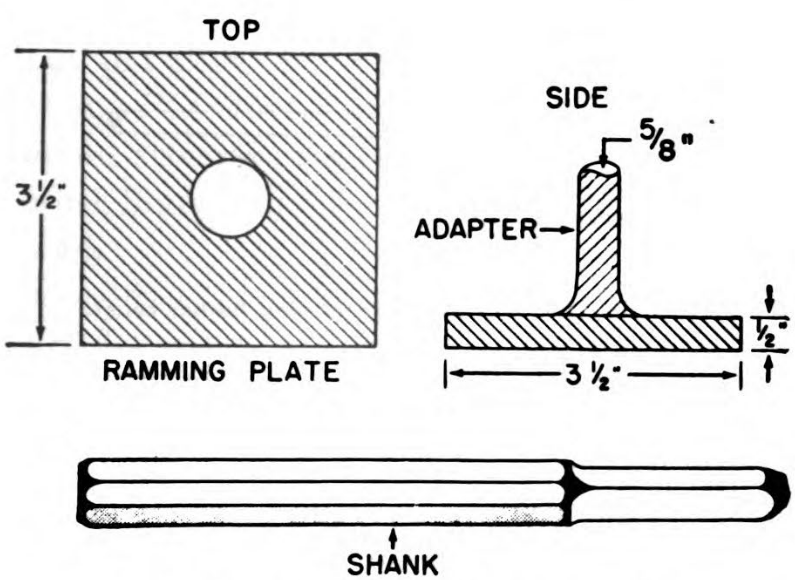


Figure 13–2.—Ramming attachment for pneumatic hammer.

Plastic Refractory Fronts

The plastic refractory around the burner openings must be inspected frequently and repaired or rebuilt whenever necessary. Plastic firebrick is generally used for both construction and repair of the area around the burner openings. Small areas of individual burner cones may be patched; however, it is not practicable to rebuild burner cones individually. The general practice in cases of severe or widespread damage is to remove the entire plastic refractory front, and then to build a new front. Standard forms are provided for shaping the burner cones.

The burner cone must be truly concentric with the atomizer. The angle of the burner cone must be exactly as specified; this angle is 35° for some types of burners, 45° for others, and 50° for others. The plastic refractory front should be rebuilt whenever burner cones are found to differ more than 5° from the specified angle.

A special tool called a SWEEP is used to cut the plastic firebrick to the proper angle, after the material has been rammed in place and the forms have been removed. A sweep is shown in figure 13–3. These tools are carried aboard ship, and are designed to suit the particular burner installations.

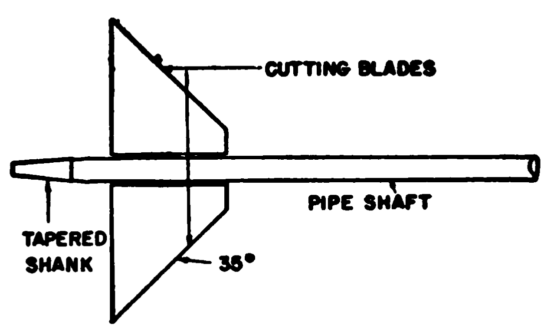


Figure 13–3.—Sweep for forming burner cones.

The sweep shown in figure 13–3 has a 35° angle; for other types of burners, a sweep with a 45° angle or one with a 50° angle would be used.

The shaft of the sweep is made of pipe the size of the burner distance piece. The cutting blades are made of iron, and are welded into slots cut in the pipe shaft. The end

of the pipe shaft may be squared to accommodate a hand crank, or it may be fitted with a tapered shank so that it can be turned by a pneumatic motor.

The pipe shaft is inserted into the burner opening, through a spider ring which is attached to the supporting ring bolt that holds the air register to the furnace front. The sweep is thus centered, and the shaft is then turned until the cone has acquired the proper shape.

Stud Tube Refractories

The refractory material applied to boiler stud tubes and headers is PLASTIC CHROME ORE (PCO). This material is a neutral refractory which makes a very strong bond with the steel studs and tubes in the water wall. Plastic chrome ore is shipped in airtight containers, and is ready for use. It must NEVER be mixed with water, cement, or any other material. Occasionally some of the liquid separates from the solid during shipment; ALL of this liquid must be thoroughly mixed with the plastic contents.

To use plastic chrome ore, remove the lid from one container, turn the drum on its side, and roll it back and forth several times. Then turn the drum upside down on a clean surface and lift it off the plastic material. Using a sharp trowel, cut the PCO into small pieces (about 1 or 2 cubic inches). If the chopped material is exceptionally moist, spread it out and allow it to dry for an hour or so. Do not use or work any PCO that shows signs of having a HARDENED CRUST. Do not attempt to salvage such material by adding water or other liquid; merely cut off the hardened part and throw it away.

Before installing the PCO on the stud tubes, be sure that the tubes are dry, clean, and free of all loose particles. Old refractory material must be removed even if it is in good condition, so that each tube is exposed at least half way around its circumference. Do not give the stud tubes any preliminary coating of other material before installing plastic chrome ore.

Begin at the bottom of the tubes and work upward. Place the PCO in position by hand; then ram it solidly, so that the finished surface is flush with the tips of the studs. The ramming must produce a dense structure around the tubes and around the studs from base to tip. Try to regulate the amount of material applied so that the hard ramming blows will give exactly the desired final level. If you apply too little PCO, do NOT add more until the surface has been made very rough. If you apply too much, do NOT try to hammer it in; instead, cut off the excess amount with a sharp trowel and refinish with a mallet.

For the ramming process, use wooden mallets as large as the size of the tubes and the space between them will permit. One face of the mallet head should be flat, while the other

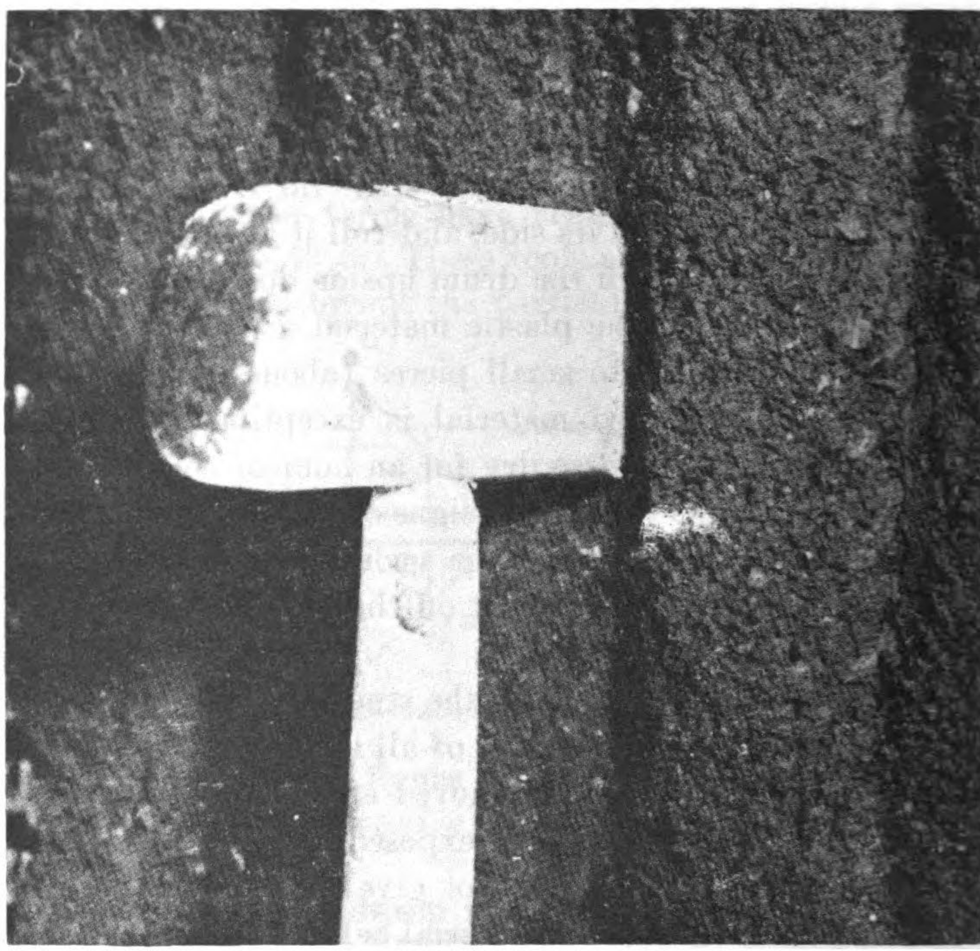


Figure 13–4.—Ramming mallet for plastic chrome ore.

face should be shaped to form the desired contour of the finished surface. A wooden mallet for ramming plastic chrome ore on stud tubes is shown in figure 13–4.

The working faces of the mallet head should be brushed frequently with a wire brush, to prevent adhesion of the plastic chrome ore.

Plastic chrome ore must always be applied to its full thickness at one time; it should NEVER be applied in layers. The material should be solidly rammed, but it should not be overrammed. Overramming is indicated by a spongy surface.

After you have finished applying PCO, do NOT slick the surface. This would produce blisters, excessive cracking, and other harmful effects. The best final surface is obtained by stippling with a wire brush, as shown in figure 13–5. The stippling provides vents for the escape of moisture, and tends to heal cracks in the refractory.

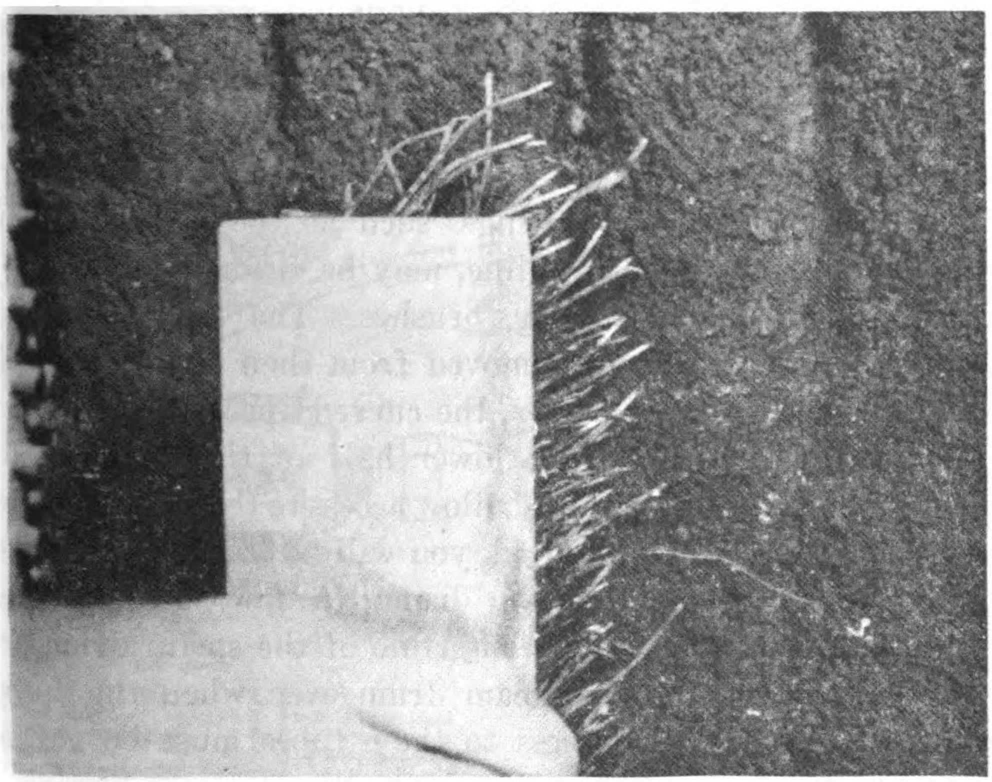


Figure 13–5.—Stippling plastic chrome ore.

Boilers must not be steamed for more than 1,800 to 2,000 hours between mechanical cleanings of the watersides. In addition, boilers should be opened and inspected whenever there is any reason to suspect that scale or other material has accumulated in drums, headers, or tubes. The results of all inspections must be entered in the boiler record sheet and in the engineering log.

At each regular cleaning period, all tubes (except superheater tubes), downcomers, drums, headers, and the economizer must be cleaned. Superheater tubes are ordinarily cleaned only at alternate cleaning periods; however, they must be inspected at the other cleaning periods, as well. For these inspections, at least one handhole should be opened on each pass of the superheater. If the tubes thus exposed are found to be dirty, the entire superheater must be opened and cleaned.

Internal Fittings

The desuperheater and some internal fittings, such as the feed pipe, swashplates, steam baffles, and the scum pan, must be removed from the steam drum when the watersides are being cleaned. Other fittings, such as the dry pipe and possibly the surface blow line, may be cleaned in place by brushing them with wire brushes. The cyclone steam separators must NOT be removed from their mountings for routine cleaning. However, the curved apron plates which follow the contour of the lower half of the steam drum MUST be removed in order to allow access to the tubes. When the apron plates are removed, you will be able to clean most of the tubes from the steam drum. A few rows of tubes just below the horizontal centerline of the steam drum are not accessible from the steam drum even when the apron plates are removed; access to these tubes must be gained through the water drums.

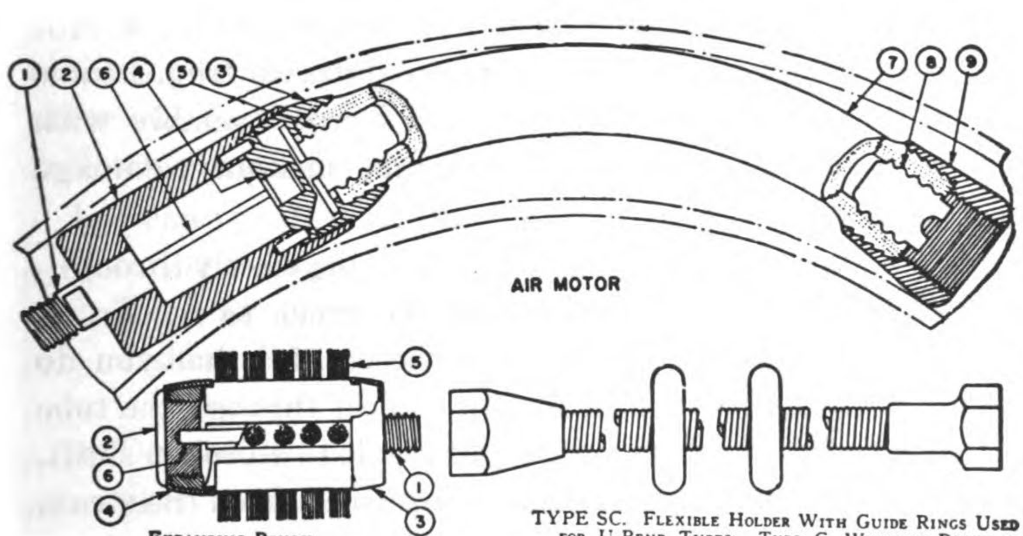
Before the apron plates are removed from the steam drum,

they should be marked to indicate their location along the curved manifold baffle. If this is not done, reassembly will be extremely difficult.

Cleaning Boiler Tubes

Two types of power-driven tube-cleaning tools are furnished for use aboard ship. Type 1 cleaners are driven by electric motors; Type 2 cleaners are driven by air motors. A Type 1 cleaner consists of the electric motor, a flexible shaft and casing, a flexible brush holder, and an expanding-type wire bristle brush. A Type 2 cleaner, shown in figure 13–6, consists of the air motor, an air hose, a flexible brush holder, and an expanding-type wire bristle brush. In addition to these shipboard types, another cleaner (Type 3) is supplied to naval shipyards, repair ships, and tenders; this type has solid steel cutting wheels with grooved edges.

Operating instructions for all three types of cleaners are essentially the same. In general, the following procedure



TYPE SC. FLEXIBLE HOLDER WITH GUIDE RINGS USED FOR U-BEND TUBES. TYPE C, WITHOUT RINGS IS FURNISHED FOR BOILER TUBES.

PARTS LIST

AIR MOTOR

1. Rotor
2. Casing cylinder
3. Retainer coupling
4. Bearing
5. Front hose expander
6. Blade
7. Flexible hose piece
8. Rear hose expander
9. Rear hose coupling

EXPANDING BRUSH

1. Body
2. Body screw
3. Retainer cap
4. End cap
5. Refill
6. Center pin

Figure 13–6.—Air-driven tube cleaner.

should be used when cleaning tubes with power-driven tube cleaners:

1. With the power shut off, insert the tube cleaner into the tube until the brush is about even with the far end of the tube. Wrap friction tape around the hose or flexible shaft to indicate how far the tube cleaner can be inserted without having the brush protrude beyond the far end of the tube. Then remove the cleaner from the tube. Remember that the tubes in each row are the same length, but that the tube length varies from row to row. Therefore, separate markings must be made on the hose or flexible shaft to indicate the tube length for EACH row to be cleaned.
2. Pass the cleaner through the tube SLOWLY, until the marker on the hose indicates that the entire length of the tube has been traversed.
3. Immediately reverse the motion and withdraw the cleaner to the inlet end.
4. Repeat the procedure, making as many passes through each tube as are necessary to clean the tube thoroughly.
5. It is not necessary to shut off the power to the tube cleaner each time the cleaner is withdrawn from a tube. However, be sure to steady the brush assembly with your hand to prevent whipping and consequent damage to parts.

In cleaning tubes, keep the cleaner moving slowly throughout the entire pass. Do not allow the brush to remain in operation at any one point. Also, be careful that you do not allow the end of the cleaner to project through the tube at the end of the pass, as this might result in a broken shaft.

Tube cleaning is most easily accomplished from the steam drum. However, some rows of tubes are not accessible from the steam drum and must be cleaned from the water drum. In addition, it is necessary to clean the lower ends of all tubes from the water drum.

Power-driven tube cleaners must be properly lubricated. The electric motor of the Type 1 cleaner should be lubricated

as indicated by the manufacturer. The air motor of the Type 2 cleaner requires lubrication after approximately 10 minutes of operation; you can tell when lubrication is needed by the fact that the cleaner will slow down.

Prepare a lubricant for the air motor by mixing one part of light lubricating oil with three parts of kerosene. Use a squirt can to inject this mixture into the air motor, through the exhaust ports. After lubricating the motor, hold the cleaner outside the boiler drum manhole and operate it until there is no sign of lubricant in the exhaust stream. Be very careful that you do not deposit lubricant within the boiler tubes or drums.

Power-driven tube cleaners must be kept clean, and they must be handled carefully. When replacing brushes or making repairs to the cleaners (as, for example, replacing turbine blades), use only the tools provided for this purpose, and be careful not to exert unnecessary pressure.

Accounting for Tools

When working in the watersides of a boiler, you should take all possible precautions to prevent tools, nuts, bolts, and other small articles from sliding down into the tubes. The following precautions are suggested:

1. Remove all small articles from your pockets before entering the boiler.
2. Keep an inventory of all tools taken into the boiler, and be sure that all tools are checked out before the boiler is closed.
3. Do not set your tools down in places where you are likely to forget about them. For example, DO NOT leave tools on top of the cyclone steam separators and in other places which are easy to reach but hard to see.
4. If some article is lost in the boiler watersides DO NOT OPERATE THE BOILER UNTIL IT HAS BEEN LOCATED AND REMOVED. Even a small article may interfere with the circulation in a boiler tube and so cause the tube to rupture.

TUBE EXPANDERS (fig. 13–7) are used to expand tubes in the boiler tube sheets. Various types of tube expanders are made, but they all consist essentially of a tapered mandrel,

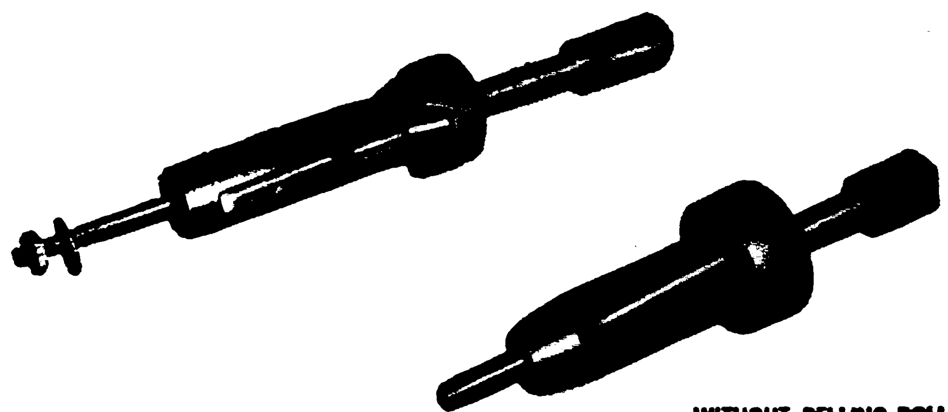


Figure 13–7.—Tube expanders.

a body, and three tapered rollers. The rollers are held loosely in slots or openings spaced evenly around the outer surface of the body. The rollers must be installed so that their taper runs opposite to the taper of the mandrel. Some types of expanders have a collar fitted to the outer end of the body; this collar rests against the tube end.

SELF-FEEDING EXPANDERS have the rollers placed at an angle to the axis of the body. The expander is inserted part way into the tube, and is drawn into it as the mandrel is turned. The mandrel can be turned by hand, by an electric motor, or by a pneumatic motor.

When expanding tubes, it is important to select a tube expander of the proper size. The rollers of the expander should be at least 3/8 of an inch longer than the thickness of the tube sheet, if complete expansion of the tube is to be obtained.

BELLING TOOLS are used for belling or flaring the ends of boiler tubes. As the tube ends must be flared to a diameter which exceeds the original diameter of the tube by at least

$\frac{1}{16}$ inch but by no more than $\frac{1}{8}$ inch, the taper of the belling tool must provide for the proper amount of belling or flaring. To use the belling tool, you place the end with the smallest diameter in the tube, and then strike the other end of the tool with heavy, solid hammer blows.

Tools for removing boiler tubes include safety ripping chisels and crimping tools. SAFETY RIPPING CHISELS are used for taking a slice cut down the inside wall of the expanded tube end. These tools are designed so that you cannot cut all the way through the tube wall and so score the tube sheet. A safety ripping chisel is shown in figure 13–8.

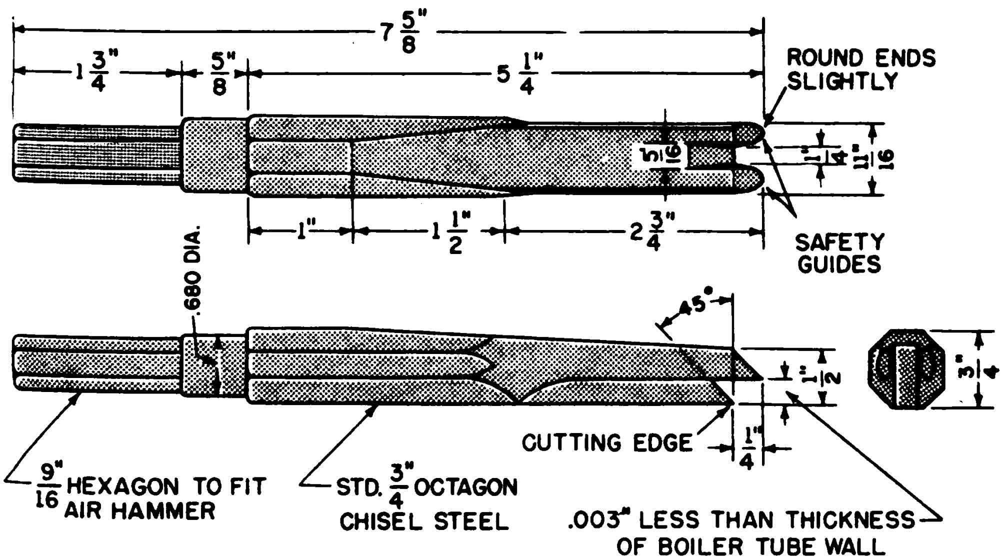


Figure 13–8.—Safety ripping chisel.

After the tube wall has been cut approximately three-fourths of the distance through the tube sheet, a CRIMPING TOOL is used to cave in the edges so that the tube may be removed from the tube sheet. A crimping tool is shown in figure 13–9.

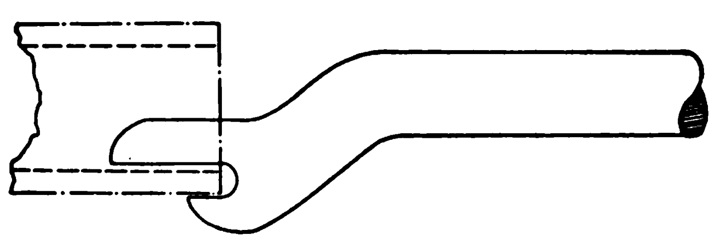


Figure 13–9.—Crimping tool.

MANHOLES AND HANDHOLES

Whenever manhole and handhole plates are removed so that a boiler may be inspected and cleaned, the manhole and handhole plates, gaskets, and gasket seating surfaces must be cleaned and tested for accuracy of fit.

The clearance between the shoulder of the manhole plate and the drum head must not exceed $1/16$ inch, when the manhole plate is centered accurately. Figure 13–10 shows where and how the clearance is measured, and also indicates the allowable clearance. If the clearance is found to be greater than $1/16$ inch, the plate should be built up by electric welding at the inner edge of the shoulder. Except in an emergency, this welding should be performed by a naval shipyard, so that the plate may be stress-relieved after it is welded, and so that the welded surface may be refaced.

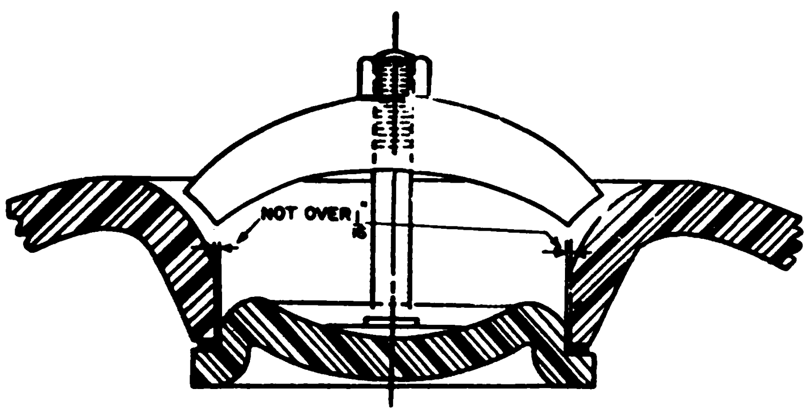


Figure 13–10.—Manhole plate clearance.

If a manhole or handhole plate is so warped that the gasket flange cannot be satisfactorily trued up, the plate should be discarded and a new one installed.

Whenever manholes or handholes are opened, new gaskets should be fitted. Always be sure to use the correct size and type of gasket. Never use graphite, oil-and-graphite mixtures, or any other make-up compound when installing gaskets on manholes or handholes on modern, high-pressure boilers.

Before new gaskets are installed, the two gasket seating surfaces (one on the plate and one on the drum head) must

be cleaned and examined for evidence of pitting or corrosion. Any pieces of old gasket material adhering to the seating surfaces must be removed by scraping, before the new gaskets are installed.

To ensure proper positioning of a manhole gasket, contract it on the long axis until the inner edge of the gasket fits the shoulder snugly at the ends of the long axis of the manhole plate. The clearance between the gasket and the shoulder should be equalized at the top and bottom of the short axis. Do NOT allow the outer edge of the gasket to protrude at any point beyond the gasket seating surface in the drum head. If an edge protrudes, the gasket may unravel when it is compressed by the tightening of the manhole cover. Any gasket which protrudes beyond the edge of the gasket seating surface should be discarded.

When the boiler is given a hydrostatic test, the pressure of the water usually forces the manhole and handhole gaskets into place and thus ensures proper seating. The plates are first set up lightly. When the boiler is ready for testing, the pressure should be pumped up to within 50 psi of the hydrostatic test pressure, regardless of any leakage from the manhole or handhole plates. Leakage is likely to be general at first, but it will decrease as the pressure is increased. When the pressure is within 50 psi of the test pressure, most of the leakage will stop, although the nuts will still be loose.

If some plates are leaking very badly, the trouble is probably due to improper seating of the gaskets. As a rule, you will find that the gasket is caught on the outer edge, between the edge of the plate and the edge of the counterbore for the seat. A light blow with a hand hammer on the outside of the plate will usually relieve the tension on the gasket and allow it to seat properly.

After leaky gaskets have been adjusted, and while full test pressure is on the boiler, all plates should be set up firmly. Use only the wrenches specified for this purpose.

Some economizer headers, and occasionally some superheater headers, are fitted with handhole plugs instead of

handhole plates. In addition, some economizers have bayonet-type clean-out plugs on the front ends of the tube loops to allow access to the tubes at the return-bend end. Detailed instructions for installing and removing the plug-type handhole fittings and the return-bend clean-out fittings are given in appropriate manufacturers' instruction books.

BOILER SLIDING FEET

At each boiler cleaning period, the sliding feet should be examined. All dirt and rust should be removed, and the sliding feet should be oiled or greased. On boilers of recent construction, grease fittings are provided for this purpose.

CASINGS, UPTAKES, AND STACK

Air leaks in boiler casings can cause a serious reduction in boiler efficiency. Such leaks may waste 10 percent or more of the fuel. Air leaking through the inner boiler casing does not become thoroughly mixed with the fuel, and therefore does not aid in combustion. Rather, it is likely to chill the heating surfaces and the gases of combustion. No air should be allowed to enter the furnace except through the air registers.

The boiler casings should be gone over completely and tested for tightness after each boiler cleaning, after each period of extended steaming, and at other times if necessary. There is no practicable way of making an INNER CASING tightness test except during a period of naval shipyard overhaul, when register openings and the base of the stack can be blanked off and portions of the outer casing removed. The OUTER CASING, however, can be tested with soapy water. The solution should be smeared along the casing joints, and the casing put under air pressure. Leakage along any of the joints will then be indicated by a line of bubbles.

All gaskets on boiler casing panels and doors must be kept in good repair, and replaced when necessary. Leaks in casing seams should be closed with a joint-sealing compound approved for boiler casing use.

The uptakes and the stack must be kept leakproof. Leaks around the base of the stack sometimes allow water to enter the boiler casing. Such leaks should be calked with a mixture of asbestos wicking and red lead.

The interior of uptakes and stacks should be cleaned by scraping and brushing. A piece of canvas should be laid across the base of the stack to catch rust or soot, and thus prevent it from falling down onto the tubes or into the furnace.

MAINTENANCE OF WATER GAGE GLASSES

Water gage glasses must be examined frequently, and defective parts replaced as necessary. The frame assemblies of water gages having flat glasses should be dismantled at regular intervals so that the condition of the mica sheets may be determined. The frames themselves should also be examined frequently for leakage around the glasses.

When the flat-type glasses are being assembled, the bolts should first be screwed fingertight. Next, they should be lightly pulled up with a wrench. When doing this, work from the center toward each end of the fitting, alternately, so that the strain will be evenly distributed. After the fitting has been installed and the boiler is under steam, the bolts should be pulled up securely; again, you should start at the center and work alternately toward each end.

Spare parts for water gage glasses must be stowed carefully. Do not permit them to come in contact with iron or steel. Do not allow the glass to become scratched.

MAINTENANCE OF SOOT BLOWERS

Soot blower piping should be inspected at each major overhaul, and at any other time when such inspection appears to be necessary. Particular attention should be given to corrosion, since there have been several serious casualties resulting from unsuspected corrosion of the soot blower supply lines. Lagging should be removed from the lines, and the exterior and interior of each section of piping should be

inspected insofar as practicable. If serious corrosion and pitting are found, the affected sections of piping should be renewed.

All moving parts of the soot blower should be inspected at regular intervals. Steam gland packing and packing in the glands (wall boxes) at the outer boiler casing should be renewed when necessary. The steam valves must be checked to see that they operate freely and that they do not leak.

On soot blowers fitted with cams, the cam settings must be checked at least once a year, to ensure proper blowing arcs. The fore and aft position of the nozzles must also be checked, to be sure that the nozzles are in the proper relationship to the tubes.

The check valve installed in the scavenging air connection to the soot blower must be kept clean and free from corrosion. This connection supplies air to the soot blower element above the steam valve, and so prevents combustion gases from backing into the soot blower head or piping. Each check valve should be disassembled as often as necessary to ensure proper operation.

Each soot blower supply line has a drain hole which MUST be kept permanently open. You can check this hole by inserting a probe into it, and also by observing whether or not steam is emitted from the hole while tubes are being blown.

Binding of soot blower elements must be corrected according to the instructions furnished by the manufacturer. In general, binding in an element which has a blowing arc of 360° may be corrected by changing the idle position from time to time so that the valve will be closed at different nozzle positions. However, this procedure must not be attempted for elements which have blowing arcs of less than 360°.

Elements which have become badly warped should be removed from the boiler and heated and straightened. Instructions for doing this will be found in the manufacturers' instruction books.

Particular attention should be paid to the IH soot blower

unit. Be sure the lines are properly drained, that the shut-off valves are tight, and that the internal sealing rings are in good condition. Be sure, also, that the blowing arc is directed toward the superheater tubes and NOT toward the water wall tubes.

When replacing parts on soot blowers, remember that the elements of multi-nozzle soot blowers are identical as to size and spacing, but are NOT made of identical material. Each element is made of metal which is suitable for the temperature to which it will be exposed; since the temperatures vary within the furnace, each soot blower element is designed for one location only. THEREFORE, THE SOOT BLOWER ELEMENTS ARE NOT INTERCHANGEABLE.

MAINTENANCE OF FIREROOM AUXILIARIES

Specific instructions for the maintenance of the various fireroom pumps and forced draft blowers have been given in the chapters in this training course which deal with the equipment. However, certain general points concerning maintenance of fireroom auxiliaries should be emphasized here.

All auxiliary machinery must be LUBRICATED in accordance with the instructions issued by the manufacturer of the equipment. When the lubrication system includes an oil reservoir, it must be kept filled to the correct level at all times, with lubricating oil of the proper weight and type. The reservoir must be drained, cleaned, and filled with fresh oil as often as required.

Lubricating oil filters must always be kept in good condition. The edge-filtration type of filter must be given one or two complete turns of the handle at the specified intervals, while the unit is in service. Periodically, the plug under the filter should be removed so that the accumulated sludge may be drawn off. From time to time, it may be necessary to dismantle the filter for cleaning.

Most lubricating oil pumps for fireroom auxiliaries are of the simple gear type. It is essential that designed clearances

be maintained in these pumps. Occasionally it may be necessary to renew the gears or the casing. Some lube oil pumps have gaskets between the casing flanges, and these gaskets require occasional replacement. If you are renewing a gasket, be sure to use one of the proper thickness. Do not attempt to fit a gasket to a lube oil pump which is not designed to have one. You should never attempt to repair this or any other type of pump without first assembling all pertinent drawings, dimensional data, and pump history.

Lubricating oil coolers should be inspected periodically to be sure that dirt and foreign matter are not allowed to accumulate in the cooling water passages. The water passages may be cleaned by water-lancing, by air-lancing, or by running rubber plugs through the tubes. Metal brushes, scrapers, or other abrasive cleaning devices should NOT be used. The oil side of a lube oil cooler may be cleaned with a solvent such as trichloroethylene. Most lube oil coolers are designed so that the bundle or core can be withdrawn from the casing for cleaning.

Zincs are used on the salt-water side of all lubricating oil coolers and other heat exchangers to protect the metal of the unit against corrosion from galvanic action. When dissimilar metals are immersed in an electrolyte (such as sea water), an electric current flows from one metal to the other through the electrolyte. The metal from which the current is flowing suffers rapid corrosion, while the metal toward which the current is flowing is protected from corrosion. When a clean zinc is installed in the water chest of a heat-exchange unit, the current flows from the zinc to the adjacent metal of the water chest; and thus the metal of the heat-exchange unit is protected.

Zinc protectors in common use include rectangular plates, circular plates, and rods or pencils. Most of the zincs used on small lube oil coolers are of the rod or pencil type. As shown in figure 13–11, the zinc rod screws into a removable pipe plug; the pipe plug, in turn, screws into the metal of the water chest.

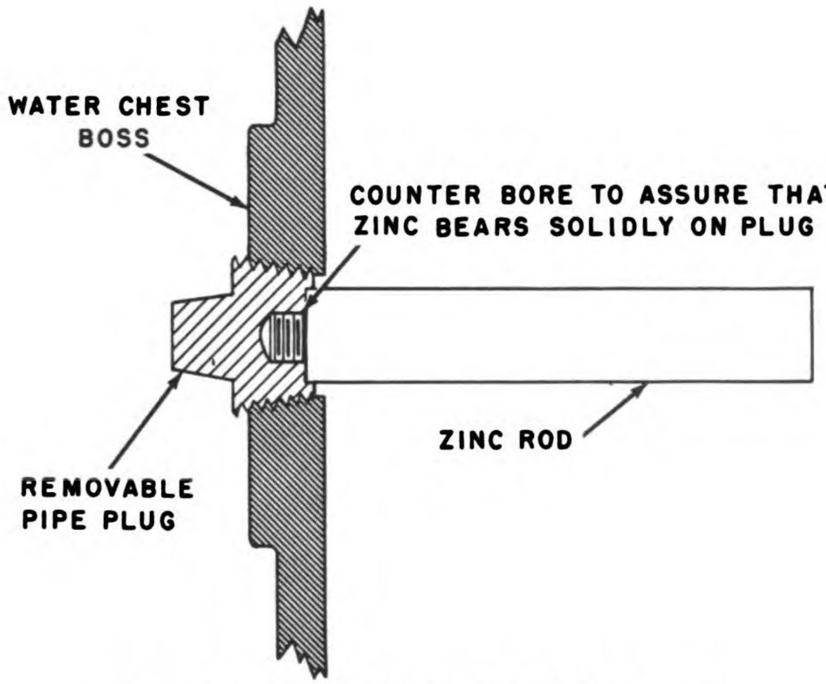


Figure 13–11.—Zinc protector for lube oil cooler.

You should be familiar with the location of all zincs installed in fireroom equipment, and with the procedures for inspecting, cleaning, and renewing them. The most important points to remember in connection with the maintenance of zincs are:

1. Inspect each zinc once a month, and clean it down to bright metal by wire-brushing or chipping. You may have to remove several layers of corrosion products before reaching the basic metal. Do not be misled by the fact that the different layers may differ in appearance—be SURE that you clean away all corrosion products. Remember, a corroded zinc gives no protection to the metal of the heat-exchange unit.
2. Keep the supporting parts, such as washers, pipe plugs, etc., free from scale. Keep the threaded parts of the supports clean and made up tightly.
3. Renew zincs when they are 50 percent deteriorated.
4. When installing or replacing zincs, be sure to make a good metal-to-metal contact between the zinc and the pipe plug. If a zinc does not deteriorate in service as rapidly as expected, it is probably not secured firmly

enough to the plug. Remember, a zinc cannot protect the metal of the heat-exchange unit unless it is in solid contact with the plug.

Figure 13–12 shows the appearance of corroded zinc rods, before cleaning.

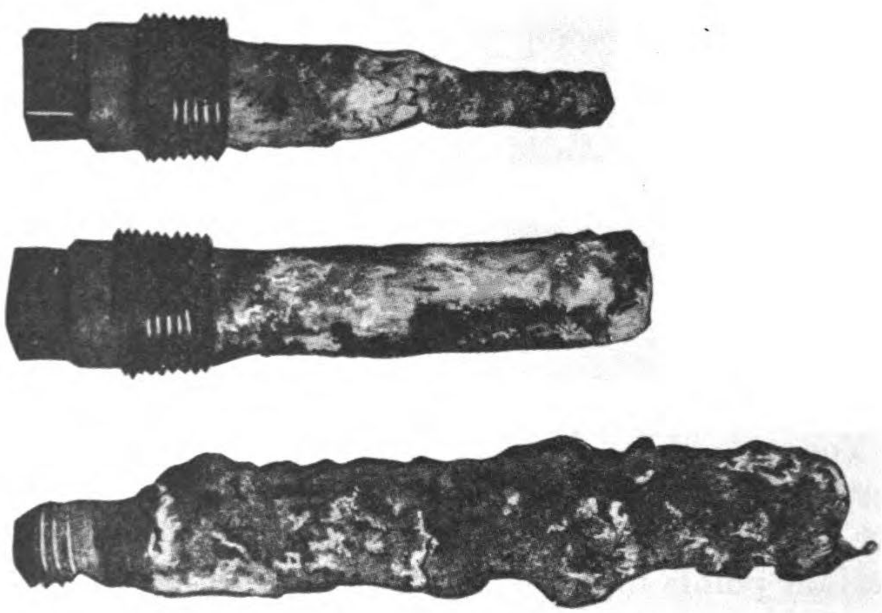


Figure 13–12.—Corroded zinc rods.

NOTE: A new type of high-purity zinc, known as ANODE ZINC, is now coming into use on naval vessels. Zinc protectors made of this material have the ability to slough off corrosion products as rapidly as they are formed. This characteristic allows the zinc to give continuous protection against galvanic action, since the zinc does not become crusted with corrosion products.

SAFETY PRECAUTIONS

Safety precautions to be observed while operating, maintaining, and repairing various fireroom units and systems have been given in appropriate places throughout this training course. The following precautions are by no means

exhaustive, but are given merely to indicate the most important precautions to be observed in boiler maintenance work. In all cases, you should read, understand, and remember the safety precautions posted on your own ship.

1. When men are working in a boiler, BE SURE that all connecting valves are closed and either locked or wired shut. Steam or hot water may enter an idle boiler through leaky bottom blow valves, steam stop valves, feed valves, superheater high-pressure drains, and so forth. Whenever possible, close and lock the guarding valves also; if this is not possible, and if pressure must be applied to any valve on an open boiler, no person shall be allowed to enter the boiler until pressure has been applied and the tightness of the valve has been assured.
2. Lash in the CLOSED position all steam-smothering control valves while men are working nearby. Be sure to remove the lashings when the work is finished.
3. Do not use naked lights in an open boiler. Use ONLY approved types of portable lights or hand flashlights. Be sure that electric leads of portable lights are properly insulated.
4. Do not allow men to enter a boiler until it has been thoroughly ventilated.
5. Observe all appropriate safety precautions when applying metal conditioning compound to boiler firesides.
6. Whenever men are working in a boiler, be sure that a man is stationed outside to give assistance in case of accident.
7. Before closing a boiler, BE SURE that no person remains inside.
8. Before closing a boiler, be sure that no foreign matter, loose material, or tools remain in any part of the boiler.

QUIZ

1. During underway steaming, how often should the soot blowers be used?
2. During in-port steaming, how often should the soot blowers be used?
3. After how many hours of steaming is it mandatory to clean boiler firesides?
4. What procedure should be followed when boiler firesides have been water-washed, and the boiler is to remain idle for an extended period of time?
5. Why must firebrick be undercut when small areas of wall are to be patched with plastic refractory?
6. When should the plastic refractory around burner openings be rebuilt?
7. How is a sweep centered on a newly repaired burner cone opening?
8. What refractory material is used in the repair of water wall stud tubes?
9. How many layers of plastic chrome ore are usually applied to a stud-tube wall?
10. What is the result of slicking the surface of PCO after ramming?
11. Why should the final surface of PCO be stippled?
12. If PCO is received too soft for installation, how should it be handled?
13. What is the maximum steaming time allowed between mechanical cleanings of boiler watersides?
14. Why should a mechanical tube cleaner always be kept moving along the length of a tube?
15. What lubricant should be used for pneumatic tube cleaners?
16. When the interior surfaces of uptakes and stacks are being cleaned, how should the furnace and the tubes be protected from soot and dirt?
17. What is the correct method of tightening the bolts on gage glasses?
18. What is the purpose of the scavenging air connection to the soot blowers?
19. Why are soot blower elements NOT interchangeable?
20. Why is it necessary to remove the plug under the edge-filtration type of filter periodically?
21. Why are zincs installed on the salt-water side of all lubricating oil coolers?

CHAPTER 14

VALVES, PIPE FITTINGS, AND PIPING

As a Boilerman, you should have a considerable knowledge of valves, pipe fittings, and piping. On board ship, you are responsible for the routine maintenance of this equipment in your assigned spaces. In addition, the qualifications for advancement in the Boilerman rating require that you understand the construction and use of the major types of valves, and that you know how to make certain repairs to valves; that you know how to disassemble, repair, and replace parts in high-pressure and low-pressure steam traps; and that you know how to replace gaskets in main and auxiliary steam lines, how to repair insulation and lagging on steam lines, and how to select gasket and packing materials.

TYPES OF VALVES

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged, and are made of either plain steel or alloy steel. Alloy steel valves are used in high-pressure, high-temperature systems; the disks and seats of these valves are usually surfaced with a chromium-cobalt alloy known as STELLITE. This material is extremely hard.

Brass and bronze valves are never used where temperatures exceed 550° F. Steel valves are used for all services above 550° F, and in lower-temperature systems where internal or external conditions of high pressure, vibration, or shock

would be too severe for valves made of brass or iron. Bronze valves are used almost exclusively in systems carrying salt water. The seats and disks of these valves are usually made of Monel, a metal which has excellent corrosion- and erosion-resistant qualities.

Many different types of valves are used to control the flow of liquids and gases. As you will remember from your study of *Fireman*, NavPers 10520–A, there are two main groups of valves. STOP VALVES are those which are used to shut off (or, in some cases, to partially shut off) the flow of fluid; these valves are controlled entirely by the movement of the valve stem. CHECK VALVES are used to permit the flow of fluid in only one direction; these valves are controlled by the movement of the fluid itself.

Valve designs vary greatly, due to the diversified demands of service. You will find some valves which are combinations of the more or less basic types just mentioned; and others which must be considered as special valves, bearing only slight resemblance to the basic types. In general, however, we may consider that stop valves include globe valves, gate valves, piston valves, plug valves, and needle valves; and that check valves include swing-check valves and lift-check valves.

Globe Valves

Globe valves are so-called because of the globular shape of their bodies. (It should be noted, however, that other types of valves may also have globe-shaped bodies; hence, the name is not always properly descriptive.)

In a globe-type stop valve, the disk, which is attached to the valve stem, seats against a seating ring or seating surface and thus shuts off the flow of fluid. When the disk is raised, fluid can pass through the valve. Globe valves may be used partially open as well as fully open or fully closed.

Globe valve inlet and outlet openings are arranged in several ways, and are used to suit the requirements of flow.

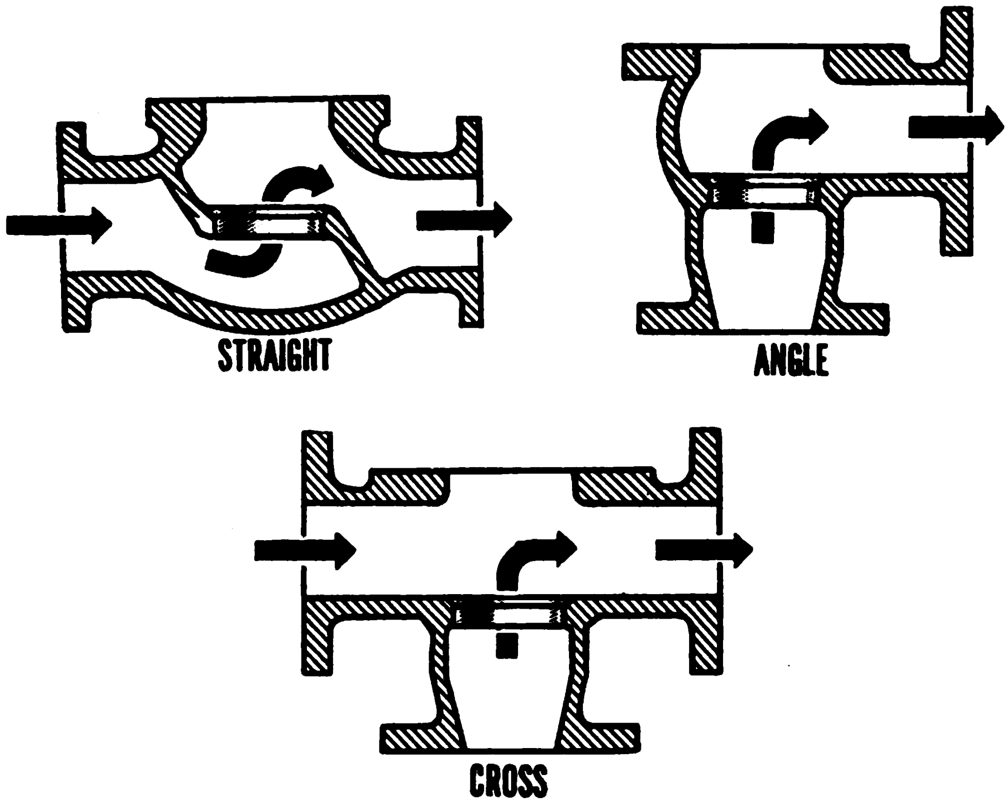


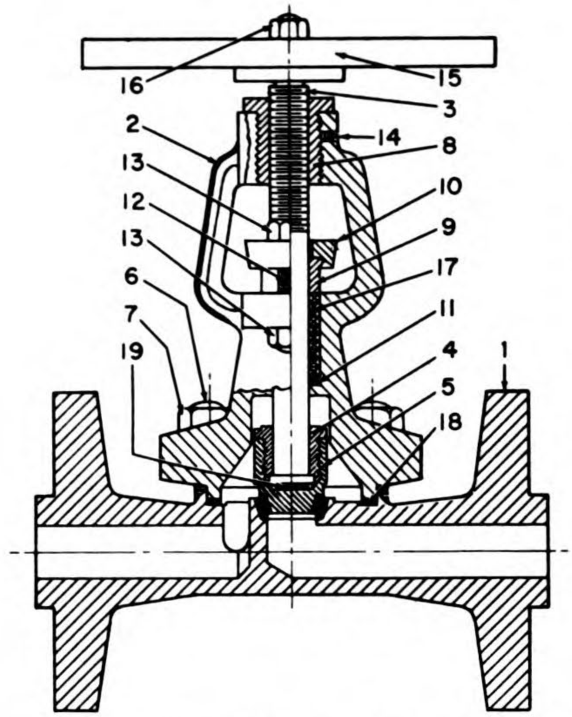
Figure 14–1.—Types of globe valve bodies.

Figure 14–1 shows three common types of globe valve bodies. In the straight type, the fluid inlet and outlet openings are in line with each other. In the angle type, the inlet and outlet openings are at an angle to each other. Angle-type globe valves are most commonly used where it is necessary to make a 90° turn in a line. The cross-type of globe valve has three openings, rather than two; it is frequently used in connection with bypass piping.

A cross-sectional view of a globe stop valve is shown in figure 14–2.

Globe valves may be installed so that the higher pressure is above the disk or below the disk. The method of installation should be governed, in each case, by consideration of the service conditions.

Pressure from BELOW the disk is desirable in cases where the flow must be continuous. For example, a globe valve installed in a boiler feed line should be installed with pressure



LIST OF PARTS	
PART NO.	NAME OF PART
1	VALVE BODY
2	BONNET
3	STEM
4	DISK NUT
5	DISK
6	BONNET STUD
7	BONNET STUD NUT
8	BONNET BUSHING
9	GLAND
10	GLAND FLANGE
11	PACKING STOP RING
12	GLAND STUD
13	GLAND STUD NUT
14	SET SCREW
15	HANDWHEEL
16	HANDWHEEL NUT
17	PACKING
18	BONNET GASKET
19	DISK WASHER

Figure 14–2.—Cross-sectional view of globe stop valve.

below the disk, since pressure from above might cause a detached disk to seat and thereby shut off the flow.

The temperature to which the valve will be exposed must also be considered in installing globe valves. If a globe valve for high-temperature service is installed with pressure under the disk, the upper part of the valve is likely to cool when the flow is shut off. Cooling of the stem might cause sufficient contraction to unseat the valve just enough to cause leakage. The resulting extremely high-velocity flow might cause severe erosion of the disk and seat. In this case, therefore, it would obviously be better to install the valve with pressure from above the disk. Remember that any valve in high-temperature service operates more efficiently if its mechanism is exposed to a constant temperature, and that this condition can be met by installing the valve so that the pressure will be above the disk.

In summary, the general rule for installing globe valves may be stated as follows: always install the valve with pressure ABOVE the disk, unless there is some special reason for installing it with pressure below the disk.

Gate Valves

Gate valves are used when a straight-line flow of fluid is desired. These valves operate on somewhat the same principle as globe valves, but have a wedge-shaped GATE instead of a disk. (The gate is sometimes referred to as a disk, because it serves essentially the same purpose.) When the gate is wide open, the opening through the valve is the same size as the pipe in which the valve is installed; therefore, there is very little resistance to flow and very little pressure drop through this type of valve. Gate valves should NEVER be used as throttling valves, since the flow of fluid against a partially opened gate can cause extensive damage to the valve.

Cross-sectional views of gate stop valves are shown in figure 14–3.

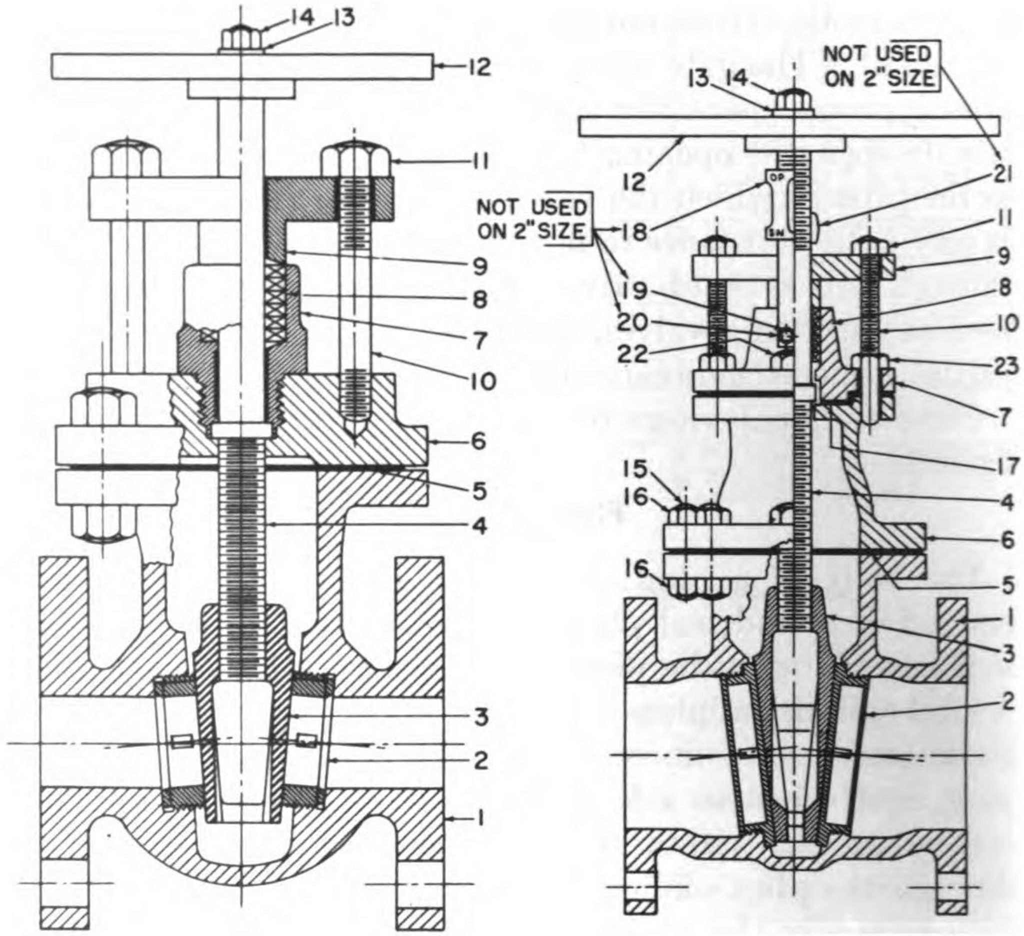
Plug Valves

The body of a plug valve is hollowed out to receive a tapered or cylindrical plug. Holes or ports in the cylinder wall line up with the pipes in which the valve is mounted. A solid cylindrical plug—or, in some cases, a plug shaped like a truncated cone—fits snugly in the hollow cylinder. The plug is attached to a handle, by means of which the plug can be turned within the cylinder. A passage is bored through the plug. When the valve is in the open position, the passage in the plug lines up with the inlet and outlet ports of the hollow cylinder, and fluid is thus allowed to flow through the valve. When the plug is turned in the cylinder, the solid part of the plug blocks the ports and stops the flow of fluid.

Three- and four-way cocks which allow selection of the routing of a fluid are usually variations of the plug valve.

Piston Valves

A piston valve is a stop valve which may be thought of as a combination of a gate valve and a plug valve. The piston valve consists essentially of a cylindrical piston operating in a hollow cylinder. The piston is attached to the valve stem, and the valve stem is attached to a handwheel.



LIST OF PARTS			
PART NO.	NAME OF PART	PART NO.	NAME OF PART
1	BODY	13	HANDWHEEL WASHER
2	SEAT RING	14	HANDWHEEL NUT
3	GATE	15	BONNET STUD
4	STEM	16	BONNET STUD NUT
5	BONNET GASKET	17	STUFFING BOX GASKET
6	BONNET	18	INDICATOR PLATE
7	STUFFING BOX	19	LOCK WASHER
8	PACKING	20	INDICATOR PLATE SCREW
9	GLAND	21	INDICATOR NUT
10	GLAND STUD	22	STUFFING BOX STUD
11	GLAND STUD NUT	23	STUFFING BOX STUD NUT
12	HANDWHEEL		

Figure 14–3.—Cross-sectional views of gate stop valves.

When the handwheel is turned, the piston is raised or lowered within the hollow cylinder. The hollow cylinder has ports in its wall. When the piston is raised, the ports are uncovered and the fluid is allowed to pass through the valve.

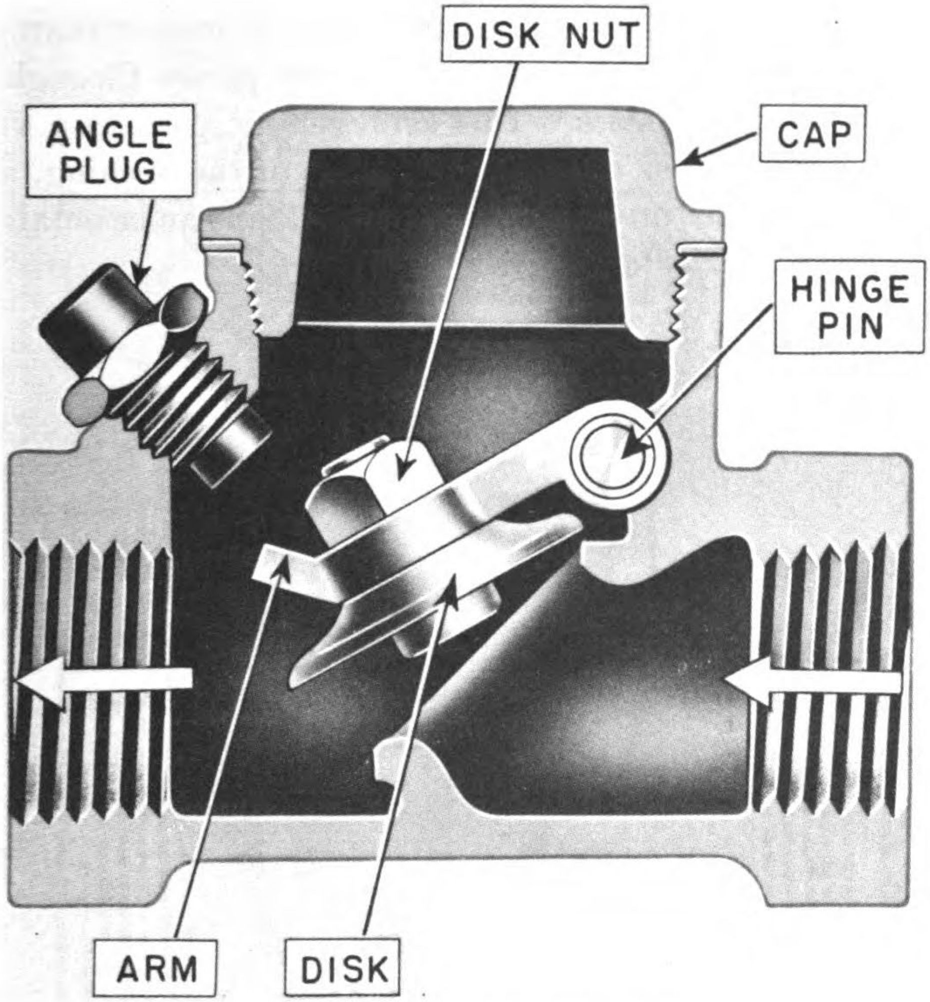


Figure 14–4.—Swing-check valve.

The tightness of this type of valve depends upon the closeness of fit between the piston and the inside of the cylinder. Some piston valves have metal rings on the piston; other types have fiber rings either on the piston or in the wall of the hollow cylinder. The fiber rings can be compressed by means of an external take-up device, so that they expand and thus prevent leakage.

Needle Valves

Needle valves are stop valves that are used for making relatively fine adjustments in the amount of fluid allowed to pass through an opening. A needle valve has a point with a long taper, at the end of the valve stem. This needle acts as a disk. The longer part of the needle is smaller than the orifice in the valve seat, and therefore passes through it before the needle seats. This arrangement permits a very gradual increase or decrease in the size of the opening, and thus allows more precise control of flow than can be obtained with an ordinary globe valve.

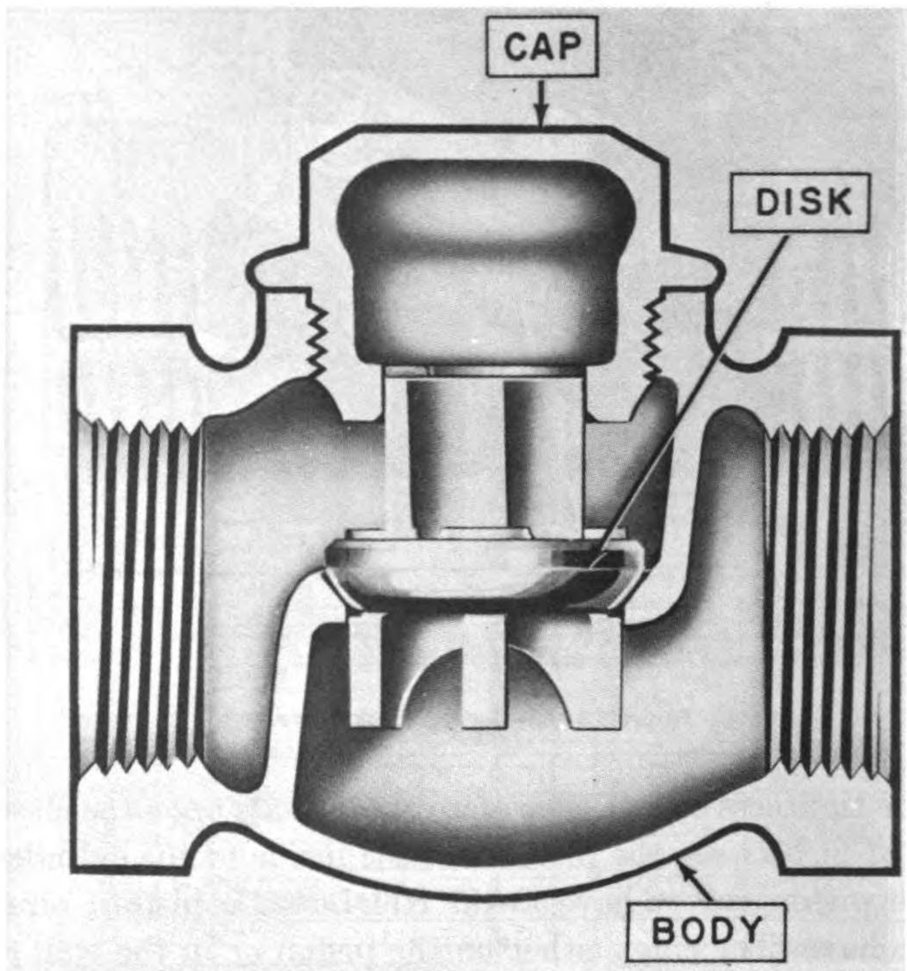
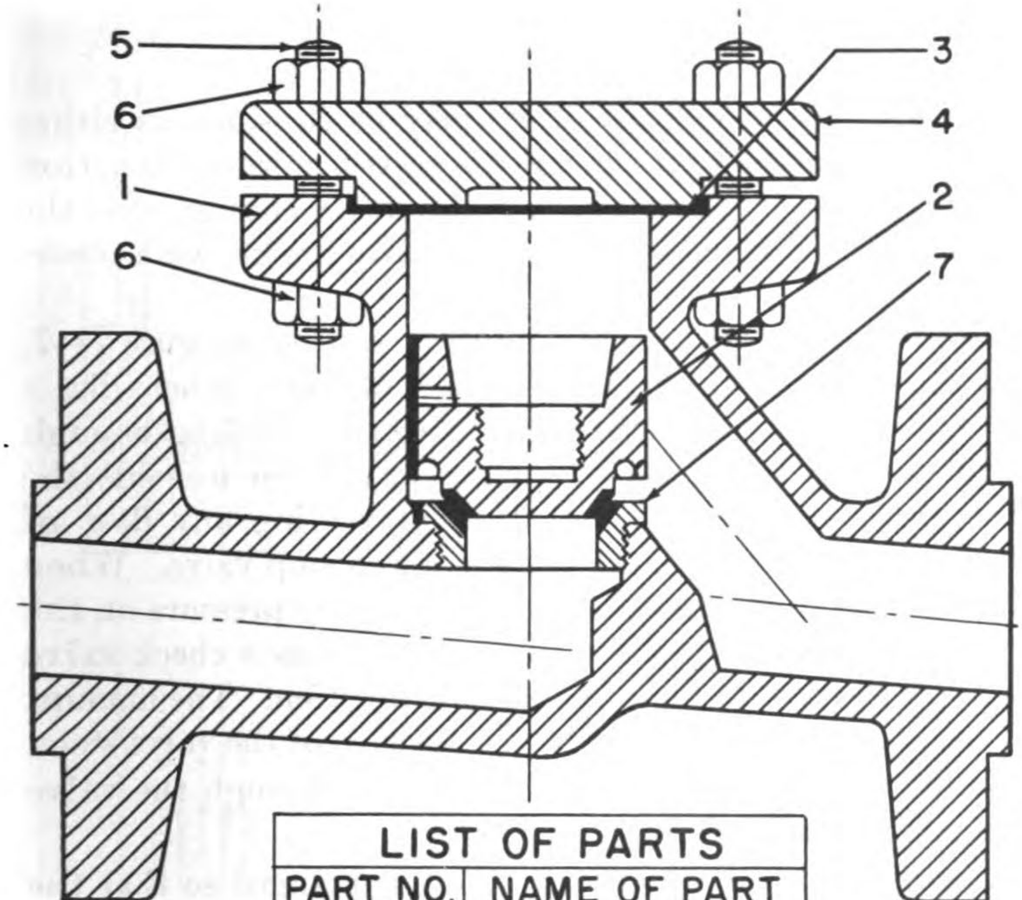


Figure 14–5.—Cutaway view of lift-check valve.

Check Valves

As mentioned before, check valves are used where it is necessary to permit fluid to flow in only one direction. A check valve opens when the pressure on the inlet side is greater than the pressure on the outlet side, and closes when the pressure on the inlet side is less than the pressure on the



LIST OF PARTS	
PART NO.	NAME OF PART
1	BODY
2	DISK
3	GASKET
4	CAP
5	CAP STUD
6	CAP STUD NUT
7	SEAT RING

Figure 14–6.—Cross-sectional view of lift-check valve.

outlet side. Check valves open and close automatically, but a valve of this type sometimes has a handle or a handwheel which may be used to lock the valve in a closed position or to limit the size of the valve opening.

A disk or a ball is generally used to close the port in a check valve. Figure 14–4 shows the type of valve known as a SWING-CHECK VALVE. Figures 14–5 and 14–6 illustrate the type of valve known as a LIFT-CHECK VALVE.

Stop-Check Valves

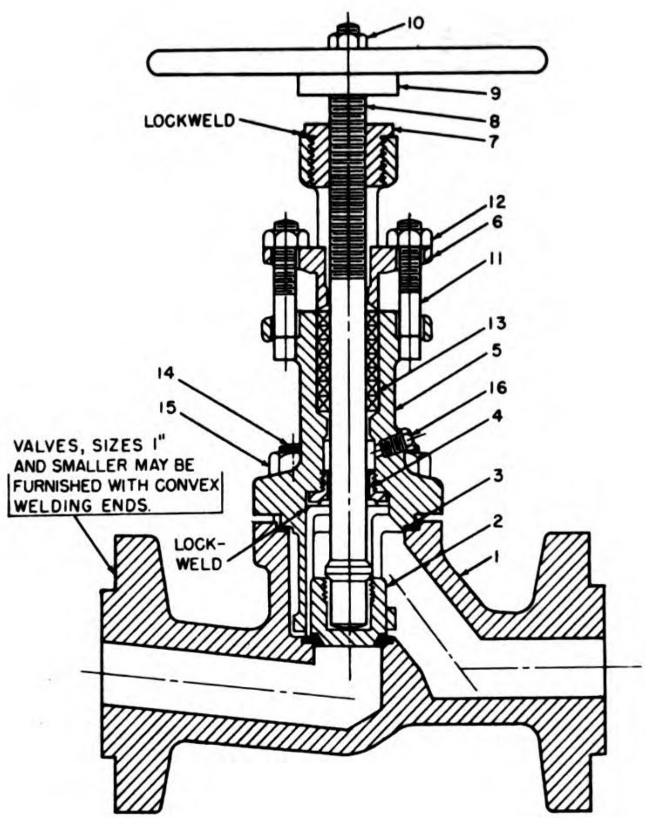
As we have seen, most valves may be classified as either stop valves or check valves. Some valves, however, function either as stop valves or as check valves, depending upon the position of the valve stem. These valves are known as STOP-CHECK VALVES.

Stop-check valves are shown in cross section in figure 14–7. As you can see, this type of valve looks very much like a lift-check valve. However, the valve stem is long enough so that when it is screwed all the way down it holds the disk firmly against the seat, thus preventing any flow of fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can be opened by pressure on the inlet side. In this position, the valve acts as a check valve to allow the flow of fluid in only one direction. The amount of the opening is controlled by the position of the valve stem, and the amount of fluid allowed to pass through the valve is thereby regulated.

Another type of stop-check valve is arranged so that the disk may be fully lifted when the valve stem is raised to its highest position. Thus, the valve acts as a stop valve when the stem is all the way down and as a check valve when the stem is partly raised, but allows the free flow of fluid in either direction when the stem is entirely raised.

FIREROOM APPLICATIONS

Some of the valves that you will find in the fireroom are good examples of the basic types of valves just described.



LIST OF PARTS	
PART NO.	NAME OF PARTS
1	BODY
2	DISK
3	GASKET
4	STEM BUSHING
5	BONNET
6	GLAND
7	YOKE BUSHING
8	STEM
9	HANDWHEEL
10	HANDWHEEL NUT
11	GLAND BOLT
12	GLAND BOLT NUT
13	PACKING
14	BONNET STUD
15	BONNET STUD NUT
16	RELIEF PLUG
17	SEAT RING
18	SPACER
19	GLAND FLANGE
20	YOKE BUSHING SET SCREW
21	JAMB NUT

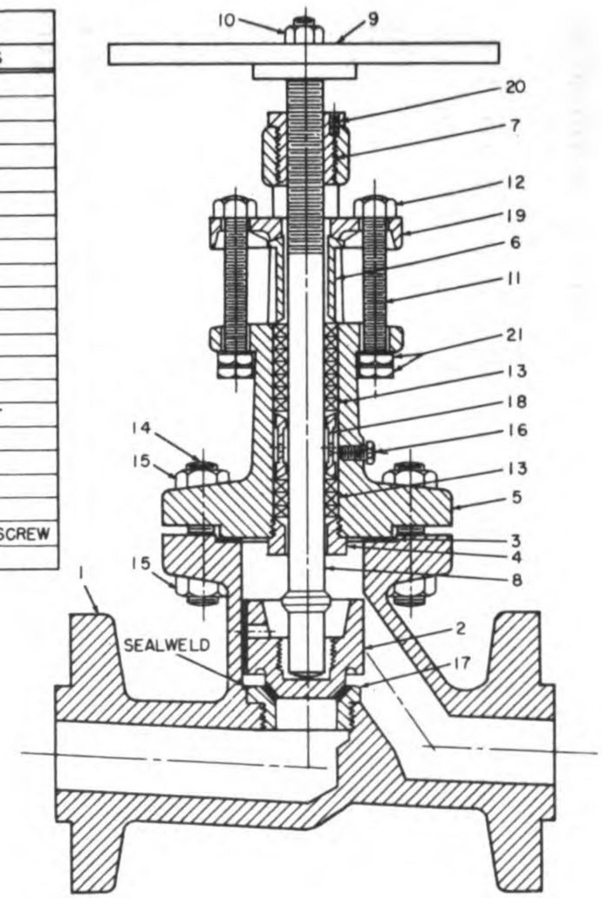


Figure 14–7.—Cross-sectional views of stop-check valves.

Others are modifications or combinations of these types. In this section we will consider some fireroom applications of the various kinds of valves.

You will probably find that GLOBE VALVES are the most commonly used type of stop valve. They are used in steam, oil, air, and water lines. The bottom blow valves, the surface blow valves, all boiler steam stop valves, and the boiler feed stop valve are globe valves. Globe valves are used as stop valves on the suction side of most fireroom pumps, and as recirculating valves in the fuel oil system. In addition, globe valves are used as throttle valves on most fireroom auxiliary machinery.

Guarding valves and line cut-out valves may be either globe valves or GATE VALVES. Firemain cut-out valves are usually gate valves. The quick-closing fuel oil valve is usually a gate valve.

The petcocks which are used as vents on lubricating oil coolers for auxiliary machinery are examples of PLUG VALVES. A modification of the plug valve, the FOUR-WAY COCK, is often used in auxiliary machinery lubricating oil systems to allow isolation of the cooler for inspection, cleaning, and repair. The shut-off device which allows fuel oil or lube oil to be diverted from one basket to another of a duplex strainer works on the same principle as the four-way cock.

The micrometer valve which is used to regulate the flow of oil to the burners may be considered as a greatly modified plug valve. It differs from an ordinary plug valve in the shape of the plug (which, in the micrometer valve, is actually a disk) ; in the shape of the passageway for the flow of fluid; and in the manner of flow through the valve. However, the micrometer valve is similar to a plug valve in that the ports in the disk must line up with the ports in the disk seating surface before oil can pass through the valve.

PISTON VALVES were formerly used for bottom blow valves on low-pressure boilers, but are not used for this purpose on high-pressure boilers. The best example of a piston valve that you are likely to see in the fireroom is the valve gear

which controls the admission and release of steam to and from each end of the steam cylinder on a reciprocating pump.

NEEDLE VALVES are used on some auxiliary turbines to control the amount of steam admitted from the steam chest to the turbine. Needle valves are quite often used as component parts of other, more complicated valves. For example, they are used on some types of constant-pressure pump governors to minimize the effects of fluctuations in pump discharge pressure.

A CHECK VALVE is installed in the line between the economizer outlet and the internal feed pipe connection. Check valves are also used in open funnel drains, in fuel oil heater drains, and in similar places where it is necessary to allow the flow of fluid in one direction but to prevent any return flow. You will also find check valves on the soot blowers, where they allow scavenging air to enter but keep steam from flowing back into the boiler casing. The groups of water-chest valves on reciprocating pumps (emergency feed pump, fire and bilge pump, etc.) are usually lift-check valves.

STOP-CHECK VALVES are quite commonly used in the fireroom. The so-called boiler feed "check" valve is actually a stop-check valve, rather than a true check valve. Stop-check valves are used for the overboard (skin) guarding valves. They are used on the discharge side of most fireroom pumps. Most exhaust valves on auxiliary machinery are spring-loaded stop-check valves of the type which may be fully closed, partially opened (acting as check valves), or fully opened. On these exhaust valves, the stem is usually fitted with a stop-collar to prevent the stem being screwed down solidly against the disk. When the valve is closed, the spring holds the disk against the seat. When the valve inlet pressure exceeds the outlet pressure (that is, the pressure in the auxiliary exhaust line) by about 2 psi, the valve opens.

VALVE MAINTENANCE AND REPAIR

The information on valve maintenance and repair which is given in this section refers primarily to globe valves and

gate valves. Plug valves usually require lathe work when they become leaky. Piston valves may require the renewal of packing or rings. The other types of valves previously discussed may be repaired in much the same manner as globe and gate valves, with appropriate modifications as necessary.

Valve repair (other than routine packing) is generally limited to overhaul of the seat and the disk. However, all other parts of the valve must be inspected and, if found to be defective, must be repaired or replaced. The valve seat and the valve disk should be closely inspected for evidence of erosion, cuts on the seating area, and improper fit of the disk to the seat. If the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are in good condition.

Spotting-In

The method used to determine visually whether or not the seat and the disk make good contact with each other is called

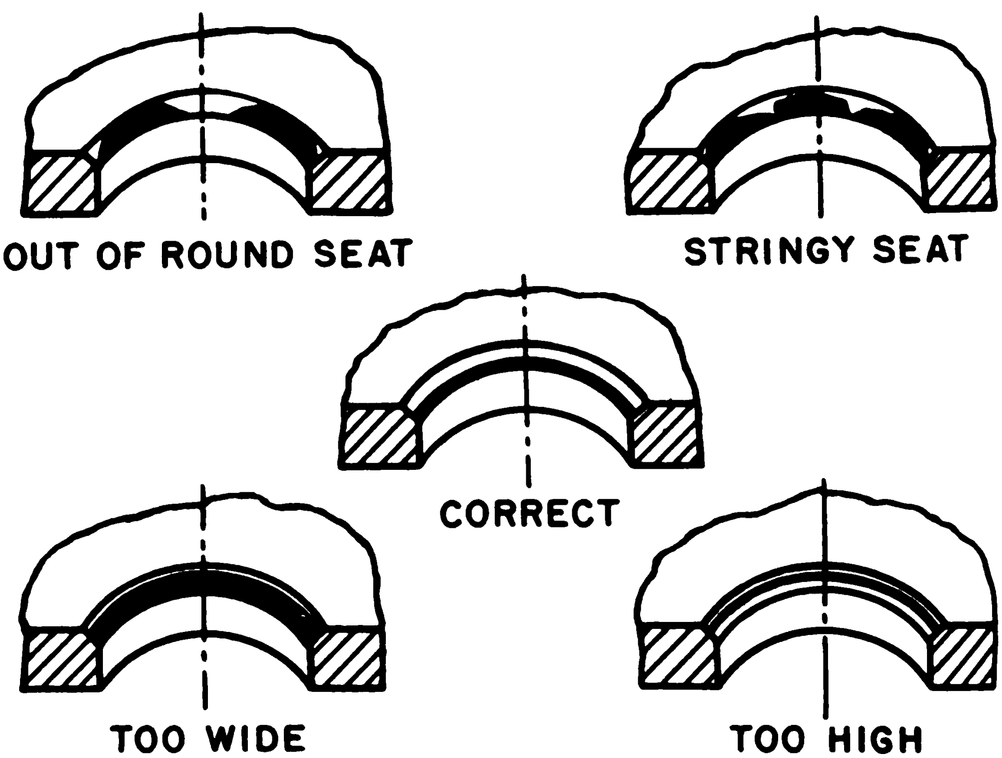


Figure 14–8.—Correct seat and various imperfect seats.

SPOTTING-IN. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using a light downward pressure. The prussian blue will adhere to the valve seat at points where the disk makes contact. Figure 14–8 shows what a correct seat looks like when it is spotted-in, and also shows what various kinds of imperfect seats look like.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussion blue to the contact face of the seat, and again place the disk on the valve seat and rotate the disk a quarter of a turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.

Grinding

Valve grinding is the method used to remove small irregularities from the contact surfaces of the seat and the disk.

To grind-in a valve, apply a small amount of grinding compound to the face of the disk. Insert the disk into the valve and rotate the disk back and forth about a quarter of a turn, shifting the disk-seat relation from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, it is necessary to stop every minute or so to replenish the compound. When you do this, you should wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat, in the manner previously described.

Grinding is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact

will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring, covering (in many valves) approximately one-third of the seating surface.

Be careful that you do not overgrind a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping

A cast iron LAPPING TOOL, or LAP is used to true the valve seat surface. Two lapping tools are shown in figure 14–9. THE VALVE DISK MUST NEVER BE USED AS A LAP.

Lapping allows you to remove slightly larger irregularities from the valve seat than can be removed by grinding. The most important points to remember while using the lapping tools are as follows:

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the valve seat so that the lap will gradually and slowly rotate around the entire seat circle.

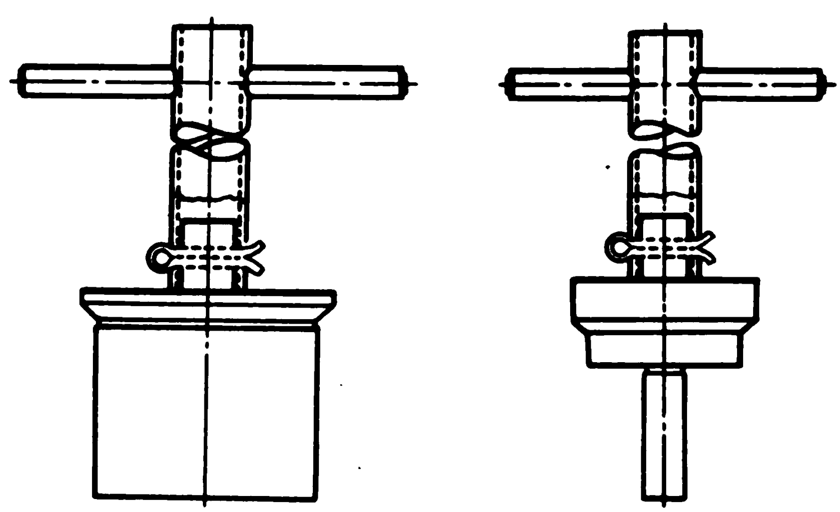


Figure 14–9.—Lapping tools.

4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use clean compound for lapping.
6. Replace the compound often.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth and even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

Lapping is the best method for correcting gate valve defects such as light pitting or scoring, and imperfect seat contact. The lapping process is the same for gate valves as it is for globe valves, except that the lap is turned by a handle which extends through the end of the valve body. The lapping tool, without its handle, is inserted into the valve in such a manner that it covers one of the seat rings. Then the handle is attached to the lap and the lapping is begun. The wedge gate can be lapped to a true surface, using the same lap that is used on the seat rings. CAUTION: Do NOT use the gate as a lap.

Lapping and Grinding Compounds

Only approved abrasives should be used for reconditioning valve seats and disks. The current specification for lapping and grinding compound is Fed. SS–C–614, Type I. This compound is supplied in six grades, four of which are suitable for lapping and grinding valve disks and seats. The coarse grade is used when extensive corrosion or deep cuts and scratches are found on the disks and seats. The medium grade is used to follow up the coarse grade, and may also be used to start the reconditioning process on valves which are not too severely damaged. The fine grade should be used when the reconditioning process nears completion. The microscopic fine grade is used for finish lapping, and for all grinding-in.

Assembling High-Pressure Steam Valves

It is extremely important to use the correct type of gasket and stud bolts and nuts when you assemble a high-pressure steam valve.

The alloy stud bolts suitable for high-temperature use may be identified in two ways: (1) the thread runs the entire length of the body, and one end of the bolt has a small center hole recess; and (2) the bolt is stamped on one end with either an "H" or an "A."

Nuts for high-temperature service have either an "H" or an "A" stamped on the crown for identification. If you do not see such an identifying letter on a nut, do NOT use the nut on a high-pressure steam valve.

When assembling a valve, use anti-seize compound on the stud bolt threads, and always be sure to back the disk away from the seat before tightening any of the bonnet nuts. In setting up on bonnet flange nuts, alternate approximately 180° and 90° from the starting point until you have all of them set up evenly and fairly tight. For final all-round setup on the nuts, use a strain gage to measure for correct tightening tension or a micrometer to measure elongation of the studs so that you can compute the tension.

PRESSURE-CONTROL VALVES

Pressure-control valves are used to relieve or to prevent excess pressure, to reduce pressure, and to control the discharge pressure of pumps. The types of pressure-control valves which you are most likely to find in the fireroom include relief valves, reducing valves, and constant-pressure pump governors.

Relief Valves

Relief valves are designed to open automatically when the pressure in the line or the unit becomes too high. There are a great many different types of relief valves, but most of them have a disk or ball which acts against a coil spring.

The spring pushes down against the disk or ball, and so tends to keep the valve closed. When the pressure in the line or the unit exceeds the resistance of the spring, the disk or ball is forced upward. The valve is thus opened, and the excess pressure is relieved.

You are already familiar with boiler safety valves, which may be considered as a particularly complicated type of relief valve. Other relief valves that you must be familiar with include those installed in steam, water, air, and oil lines, and on various units of auxiliary machinery. As a Boilerman, you will be required to know how to set relief valves on all fireroom auxiliary machinery. Spring tension may be changed by means of an adjusting nut at the top of the valve. The correct setting for each relief valve should be obtained from the manufacturer's instruction book for the unit on which the relief valve is installed, or from the piping system blueprint, as appropriate.

Reducing Valves

Reducing valves are automatic valves which are used to provide a steady pressure lower than the supply pressure. Reducing valves are used on gland seal lines, galley steam lines, heating system lines, and on many other reduced-pressure lines. A reducing valve can be set for any desired discharge pressure, within the limits of the design of the valve. After the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the desired delivery pressure) and regardless of the amount of reduced-pressure steam that is used. Two general types of reducing valves are in common use: the spring-loaded reducing valve, and the pneumatic-pressure-controlled (or gas-loaded) reducing valve.

The principal parts of a SPRING-LOADED REDUCING VALVE are: (1) the main valve, an upward-seating valve which has a piston on top of its valve stem; (2) an upward-seating auxiliary (or controlling) valve; (3) a controlling diaphragm; and (4) an adjusting spring.

High-pressure steam (or other fluid) enters the valve on the inlet side and acts against the main valve disk, tending to close the main valve. However, high-pressure steam is also led through ports to the auxiliary valve, which controls the admission of high-pressure steam to the top of the main valve piston. The piston has a larger surface area than the main valve disk; therefore, a relatively small amount of high-pressure steam acting on the top of the main valve piston will tend to open the main valve, and so allow steam at reduced pressure to flow out the discharge side.

But what makes the auxiliary valve open, to allow high-pressure steam to get to the top of the main valve piston? The controlling diaphragm transmits a pressure downward upon the auxiliary valve stem, and thus tends to open the valve. However, reduced-pressure steam is led back to the chamber beneath the diaphragm; and this steam exerts a pressure upward on the diaphragm, which tends to close the auxiliary valve. The position of the auxiliary valve, therefore, is determined by the position of the controlling diaphragm.

The position of the diaphragm at any given moment is determined by the relative strength of two opposing forces: (1) the downward force exerted by the adjusting spring; and (2) the upward force which is exerted on the under side of the diaphragm by the reduced-pressure steam. These two forces are continually seeking to reach a state of balance; and, because of this, the discharge pressure of the steam is kept constant as long as the amount of steam used is kept within the capacity of the valve.

Figure 14–10 shows the construction and indicates the manner of operation of a PNEUMATIC-PRESSURE-CONTROLLED (or GAS-LOADED) REDUCING VALVE. A rubber diaphragm is installed in the middle of the dome. The bottom of the diaphragm is separated from the bottom half of the dome by a fixed steel plate. The area immediately above the diaphragm communicates with the upper part of the dome through holes in the shrouding. The upper half of the dome

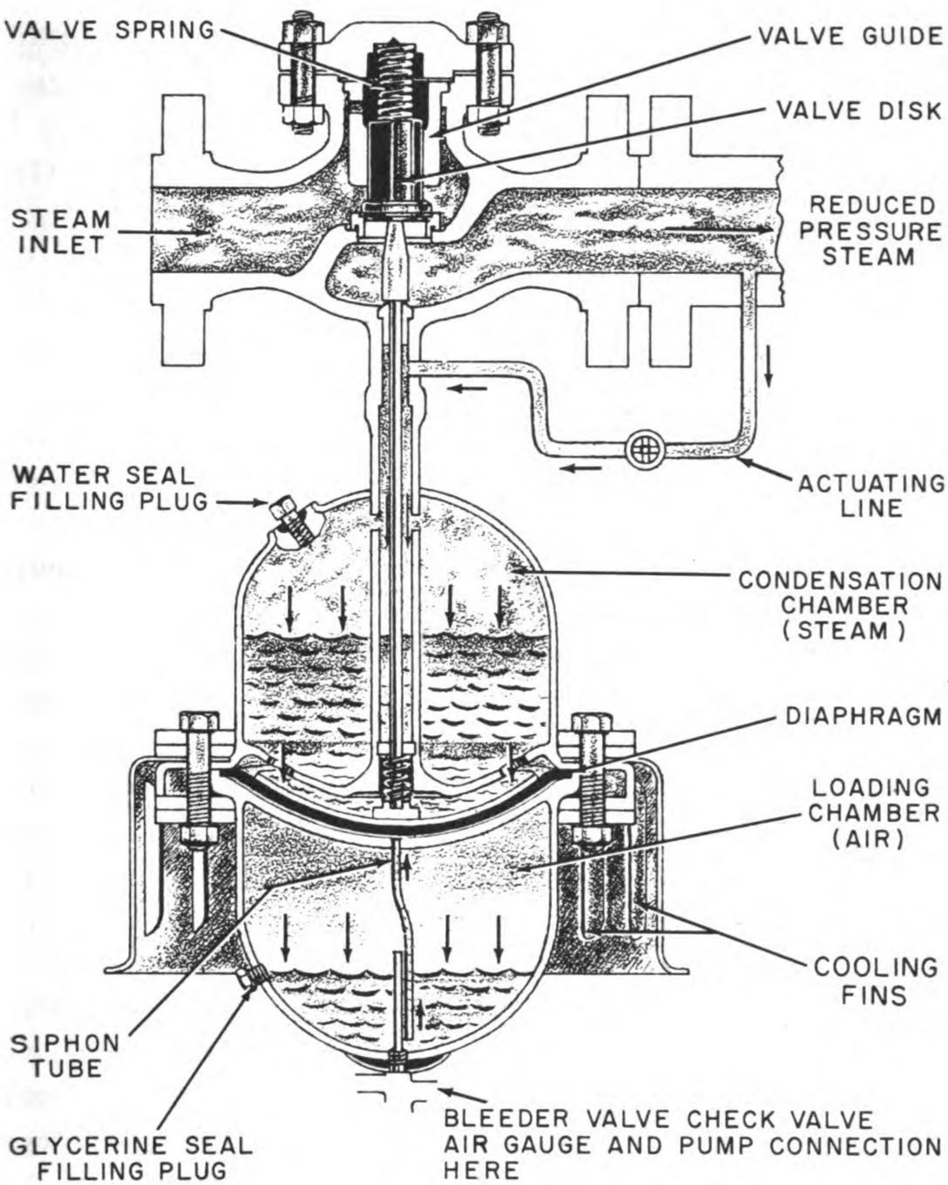


Figure 14–10.—Pneumatic-pressure-controlled reducing valve.

carries a level of water for sealing; the lower half of the dome carries a level of glycerine for sealing. The area above the glycerine is charged with air, which exerts a downward pressure on the glycerine and forces some of it to go up the tube toward the diaphragm. This pressure causes the diaphragm to move upward; and, since the stem of the valve is in contact with the diaphragm, the upward movement of the diaphragm causes the valve to open. When the valve is open, steam can pass through the valve.

From the outlet connection, an actuating line leads back to the upper part of the dome, in the manner shown in figure 14–10. Steam at the reduced pressure is thus allowed to exert a force on the top of the water seal; this force is transmitted through the water and tends to move the diaphragm downward. When the pressure of steam from the actuating line exceeds the loading air pressure in the lower half of the dome, the diaphragm moves downward sufficiently to close the valve. The closing of the valve reduces the pressure of the steam on the discharge side of the valve. When the pressure on the outlet side of the valve is equal to the air pressure in the lower half of the dome, the valve takes a balanced position which allows the passage of sufficient steam to maintain that pressure.

If the load increases, tending to take more steam away from the valve, the outlet pressure will be momentarily reduced. Thus, the pressure of steam on top of the diaphragm becomes less than the pressure of air below the diaphragm, and the valve then opens wider to restore the outlet pressure to normal. If the load is reduced, this causes a momentary increase in outlet pressure, and this in turn increases the pressure on top of the diaphragm above that of the air pressure below it, causing the diaphragm to be displaced downward. The outlet pressure is again restored to normal.

Thus, theoretically, the valve should deliver a pressure of steam equal to the pressure of air pumped into the lower half of the dome. However, since the valve itself has weight and is equipped with a light spring which tends to close it, it is necessary to introduce slightly more air pressure than is theoretically required. For the higher pressure valves, about 10 psi additional air pressure is required. If air is pumped in when the valve is cold, slightly less air pressure will be needed because the air pressure will increase slightly when the valve is warmed up.

The cooling fins extending outside the dome from the center flange appear only on the high-pressure valves. They are installed to allow for transmission of heat from the upper half of the dome to the atmosphere and to keep heat from

passing into the lower half, where it may cause an excessive rise in the air pressure.

When the reducing valve is being put into operation, the discharge valve should be opened first. Then, if proper air pressure is in the dome, the inlet valve should be opened slowly, allowing the valve to heat up. The valve in the actuating line must be open. It will be difficult to get these valves on the line unless some steam is being bled away from the discharge. If you are careful to warm up reducing valves properly and to put them on the line slowly, no trouble should be encountered with their operation. Glycerine should always be used for the lower seal. Water should be used for the upper seal; the condensation of steam in the upper part of the dome is usually sufficient to maintain the water seal at the proper level.

Constant-Pressure Pump Governors

Constant-pressure pump governors operate on much the same principle as spring-loaded reducing valves. There is, however, one important difference between the pump governor and the regular reducing valve. In the reducing valve, the reduced-pressure steam on the discharge side is used to exert an upward pressure on the diaphragm and so maintain a constant reduced pressure in the discharge line. In the constant-pressure pump governor, the discharge pressure of the pump (rather than the discharge pressure of the steam) performs this function. The pump discharge pressure is therefore kept constant, because this pressure regulates the flow of steam to the pump turbine. It is important to note that the pressure of the steam on the discharge side of the governor is NOT constant, but varies as necessary to keep the pump discharge pressure constant.

The two constant-pressure pump governors which are most commonly used in the Navy are the Leslie and the Atlas governors. A third type (Foster) was formerly used, but is now being replaced with Leslie or Atlas governors. The

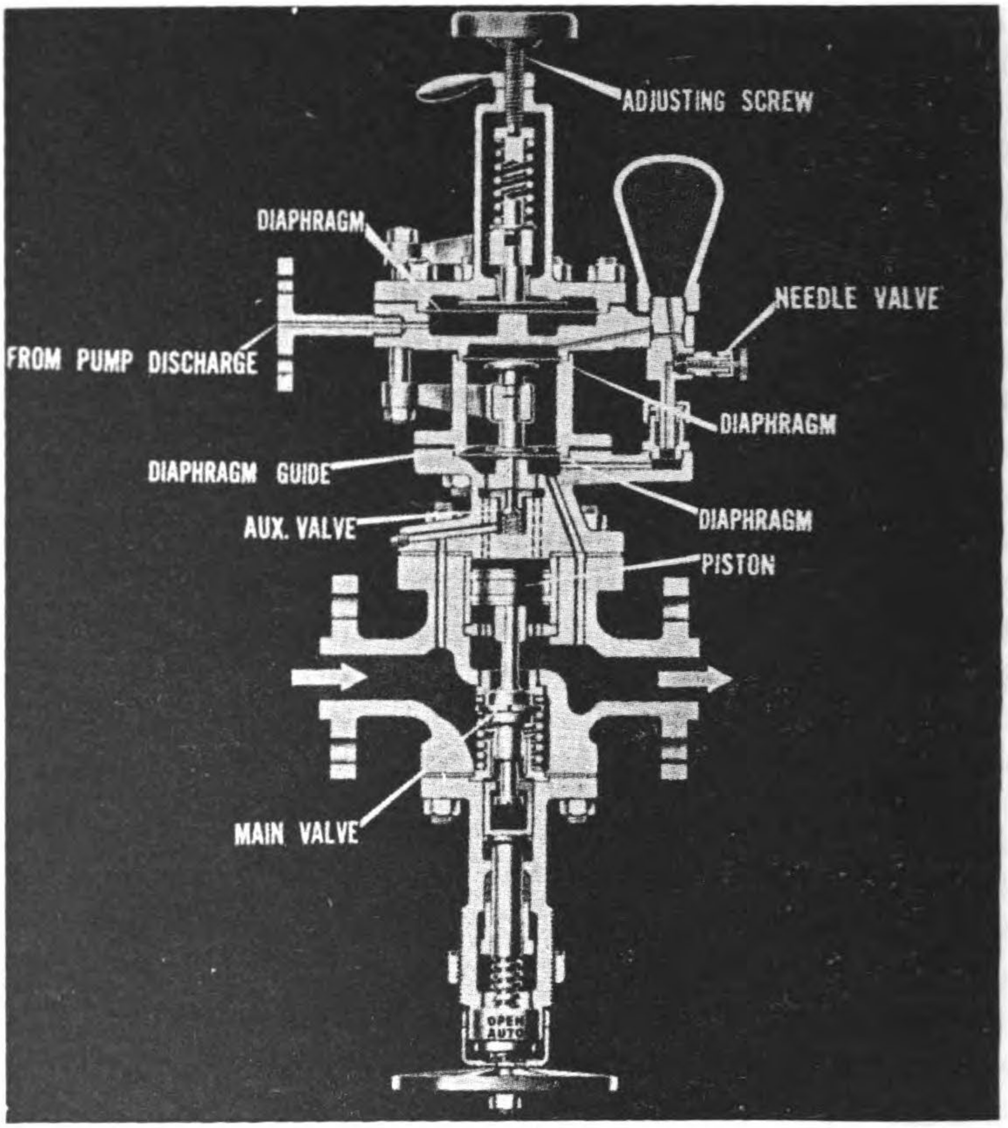


Figure 14–11.—Constant-pressure pump governor for lubricating oil service pump.

Leslie and the Atlas governors are very similar in operation and construction, and the following description applies, in general, to both types.

A constant-pressure pump governor for a lubricating oil service pump is shown in figure 14–11. The governors used on fuel oil service pumps and on main feed pumps are of the same type, except that the size of the upper diaphragm and the amount of spring tension are different on governors used for different services.

The adjusting spring exerts pressure downward on the upper diaphragm, through a crosshead and mushroom arrangement. When there is no pump discharge pressure, the spring forces the upper diaphragm and the upper crosshead down. A pair of connecting rods connects the upper crosshead with the lower crosshead, so the lower crosshead is moved down with the upper one. When this happens, the lower diaphragm is displaced downward by the lower mushroom, and the auxiliary valve disk is forced open. The auxiliary valve is supplied with steam from the inlet side of the governor; and when the auxiliary valve is open, steam passes through ports to the top of the operating piston. The steam pressure on the top of the operating piston forces it downward and opens the main valve, thereby admitting more steam to the pump turbine and increasing the speed of the turbine.

The increased speed of the turbine is reflected in an increased discharge pressure from the pump. This pressure is exerted against the under side of the upper diaphragm, through an actuating line. When the force below the diaphragm is greater than the force represented by the tension of the adjusting spring, the diaphragm is displaced upward. This causes a reduction in the size of the auxiliary valve opening and allows a spring to start closing the main valve against the now reduced pressure on the operating piston. When the main valve starts to close, the steam supply to the turbine is reduced, the pump is slowed, and the discharge pressure is decreased.

Steam from the main valve outlet is led through ports to chambers above and below the sealing diaphragms. A needle valve and a surge chamber (or steam chamber) are used to delay and minimize the effects of main valve outlet pressure changes upon the pressure above the top sealing diaphragm; and they thus serve to dampen excessive reactions of the auxiliary valve to variations in pump discharge pressure.

With the unit under constant-load conditions, the operating piston takes a position which holds the main valve

open by the required amount. A change in load conditions results in momentary hunting by the governor, until it finds the new position required to maintain pressure at the new load.

Two adjustments are required on the constant-pressure pump governor: (1) the adjusting screw must be set to regulate the discharge pressure of the pump, and (2) the needle valve must be set to minimize hunting. The adjustment of the needle valve should be made while the pump is operating under a light load at normal discharge pressure.

The constant-pressure pump governor may be set for either automatic control or manual control. Under normal operating conditions, the automatic setting is used. When it is desired to control the pump manually, the valve stem below the main valve must be set to hold the main valve fully open. In this position, the valve allows a full flow of steam to the turbine; and control of turbine speed must, therefore, be achieved by means of hand throttling.

PIPE FITTINGS

As a Boilerman, you should be familiar with the various types of fittings which are usually installed in piping systems. Valves, which have already been discussed in this chapter, are actually pipe fittings that serve to control the amount and direction of flow. Other fittings commonly found in fireroom piping systems include strainers and steam traps.

Strainers

Strainers are installed in almost all piping lines to prevent the passage of foreign matter which might cause damage to machinery. A bilge suction strainer is shown in figure 14–12. As you can see, this basket strainer keeps foreign matter from going to the bilge pump suction.

A steam strainer is shown in figure 14–13. Steam strainers are installed in steam lines in order to protect machinery against scale and other foreign matter. Steam strainers are

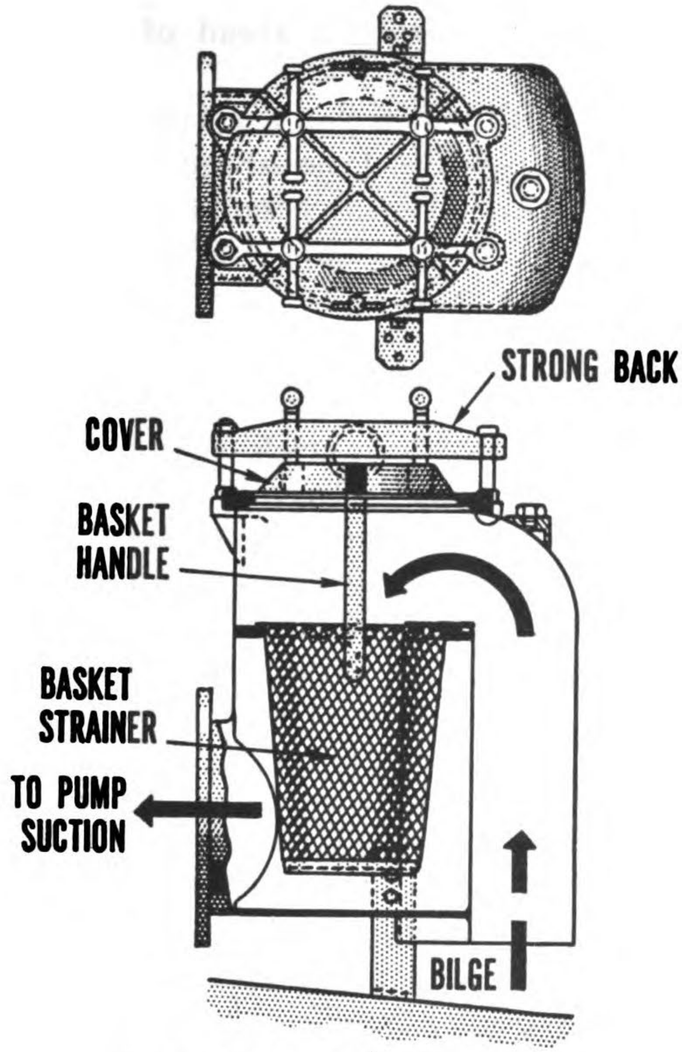


Figure 14–12.—Bilge suction strainer.

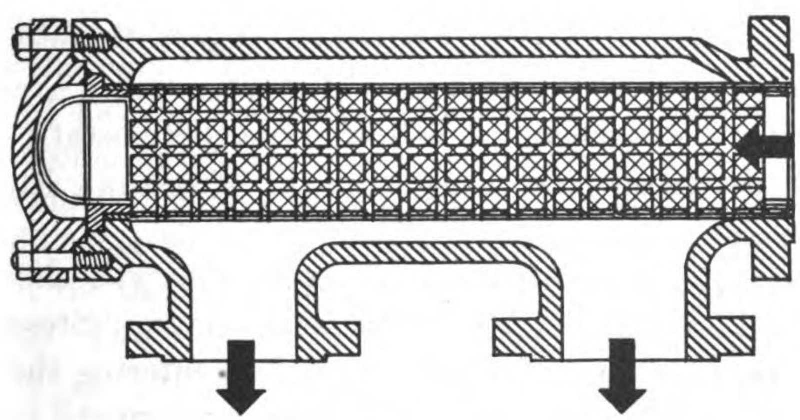


Figure 14–13.—Steam strainer.

installed in the steam lines just ahead of most auxiliary turbines.

Other strainers with which you are familiar include the duplex, high-pressure, basket-type strainers installed on the discharge side of the fuel oil service pump; strainers installed on the suction side of many pumps; and the edge-filtration type filters installed in many lubricating oil systems.

Steam Traps

Basic information on steam traps is given in *Fireman*, NavPers 10520–A. As you will remember, steam traps are installed in steam lines to remove condensate. Some steam traps are suitable for low-pressure use and others for high-pressure use. Essentially, however, any steam trap consists of a valve and some device or arrangement which will cause the valve to open and close, as necessary, to drain the condensate from the line without allowing the escape of steam. The three types of steam traps which are most commonly used are: (1) mechanical, (2) thermostatic, and (3) flash, or impulse.

MECHANICAL STEAM TRAPS may be of the ball float type, or of the bucket type. The ball float type is suitable only for low-pressure use. The bucket type is sometimes used for high pressures and temperatures. The maintenance and repair work required for these traps is about the same as that required for valves.

THERMOSTATIC STEAM TRAPS have expansion tubes or bellows which expand and thereby close the valve when a certain temperature is reached. A bellows-type thermostatic steam trap is described and illustrated in *Fireman*, NavPers 10520–A.

FLASH (or IMPULSE) STEAM TRAPS of the type shown in figure 14–14 are used for high-pressure service. Steam and condensate pass through a strainer before entering the trap. A circular baffle serves to keep the entering steam and condensate from impinging on the cylinder or on the disk.

The impulse type of steam trap depends for its operation

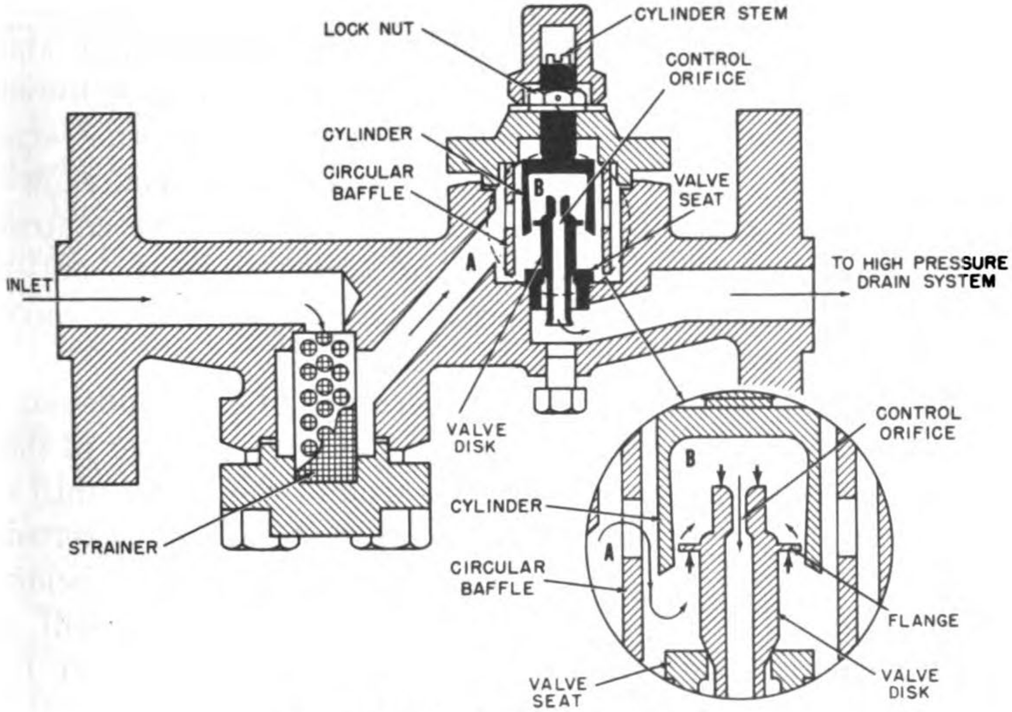


Figure 14–14.—Impulse steam trap.

upon the fact that hot water under pressure tends to flash into steam when the pressure is reduced. In order to understand how this principle is utilized, let's consider the arrangement of parts shown in figure 14–14 and see what happens to the flow of condensate under various conditions.

The only moving part in the steam trap is the disk. This disk is rather unusual in design. Near the top of the disk there is a flange which acts as a piston. (As you can see in figure 14–14, the working surface above the flange is larger than the working surface below the flange; the importance of having this larger effective area above the flange will become apparent later in this discussion.) A control orifice runs through the disk from top to bottom, being considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the flange) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the flange and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first cut in, pressure from the inlet (chamber A) acts against the underside of the flange and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat; and, at the same time, a small amount of condensate (called CONTROL FLOW) flows up past the flange and into chamber B. The control flow discharges through the control orifice, into the outlet side of the trap, and the pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the flange until a balanced position is reached in which the total force exerted above the flange is equal to the total force exerted below the flange. It is important to note that there is still a PRESSURE DIFFERENCE between chamber A and chamber B. The FORCE is equalized because the effective area above the flange is larger than the effective area below the flange. The difference in working area is such that the valve maintains an open, balanced position when the pressure in chamber B is 86 percent of the pressure in chamber A.

As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low-pressure area. Since the steam has a much larger volume than the water from which it is generated, pressure is built up in the space above the flange (chamber B). When the pressure in this space is greater than 86 percent of the inlet pressure, the force exerted on the top of the flange pushes the entire disk downward and so closes the valve.

With the valve closed, the only flow through the trap is past the flange and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing. Pressure in chamber B is thus reduced to the point where the valve opens and allows condensate to flow through the orifice in the valve seat. Thus the cycle is repeated.

With a normal condensate load, the valve opens and closes at frequent intervals, discharging a small amount of condensate at each opening. With a heavy condensate load, the valve remains wide open and allows a heavy, continuous discharge of condensate.

The strainer which is installed ahead of each steam trap must be kept clean and in good condition, to prevent scale or other foreign matter from getting into the trap itself. If the trap valve does not open or close properly, the difficulty is probably due to scale clogging the control orifice, the orifice in the valve seat, or the space between the flange and the cylinder.

To clean the working parts of the impulse steam trap, you must first cut out the trap. Then remove the bonnet. Since the cylinder is attached to the bonnet, the cylinder and the disk comes out together when the bonnet is removed. To remove the disk from the cylinder, you must set the disk at an angle to the cylinder and then roll the flanged part out edgewise. After cleaning the valve parts, insert the disk into the cylinder and reassemble the trap. You should always install new gaskets before reassembling the trap.

The cylinder and disk should be replaced as a unit, if either is damaged. Replacement of either part separately might result in improper clearance between the flange and the cylinder, with consequent poor operation of the trap.

PIPING

As a Boilerman, you will be required to install or patch insulation and lagging on steam lines and on other fireroom piping. It is important for you to know what materials are suitable for the various services, and to know how to apply these materials.

In general, the materials used to insulate piping include (1) the insulating material proper; (2) the lagging, or covering; and (3) the fastenings which are used to hold the insulation and lagging in place. In some instances, the insulation is covered by material which serves both as lagging and as a fastening.

Insulating materials must always be selected with regard to the temperatures to which they will be exposed. In addition to the actual insulating characteristics of the material, such characteristics as structural strength, resistance to shock and vibration, chemical stability, fire-resistance, and ease of application and repair must be considered. Insulating materials commonly used on high-temperature piping include magnesia-asbestos composition, mineral or rock wool, asbestos, fibrous glass, and several types of insulating cements.

Magnesia-asbestos pipe covering is most commonly used as insulation on high-temperature piping. This material is supplied in molded sections, which are 3 feet long; each section is split in half, lengthwise. Suitable widths are available to fit the various pipe sizes. Magnesia-asbestos pipe covering comes in three grades; Grades I, II, and III are suitable for temperatures up to 500° F, 750° F, and 850° F, respectively.

Mineral or rock wool is supplied in wire-reinforced pads. This material is suitable for high-temperature use, and is particularly useful for insulating large areas.

Asbestos is used for many insulating purposes, and is provided in various forms. Asbestos cloth is used as lagging over insulating material on valves, fittings, flanges, and pipes. Asbestos felt is used for both low-temperature and high-temperature insulation. Flameproof asbestos in the form of a soft, flexible sheet is used for lagging and insulation where space does not permit thicker or more rigid forms of insulation.

Fibrous glass is supplied in many forms, for a variety of lagging and insulation uses. Fibrous glass bonded to form a semirigid sheet is used for insulating boiler uptakes. Fibrous glass lagging comes in tape form, to be used over insulation on piping.

Insulating cements are used for patching, for emergency repairs, and for covering small, irregular surfaces such as

valves, flanges, and joints. Cements used for high-temperature work include asbestos cements, diatomaceous earth cements, and mineral or rock wool cements.

Applying Insulation

All sections or segments of pipe coverings should be tightly butted at joints, and should be secured with wire loops, metal bands, or lacing. Insulating cement should be used to fill all crevices, to smooth surfaces, and to coat wire netting before final lagging is applied.

Do not allow the insulating materials to become moist. Moisture impairs the insulating value of the material, and may cause eventual disintegration. Large air pockets in the insulation cause large heat losses, so be sure to fill and seal all cavities or cracks. Hangers or other supports should be insulated so as to prevent loss of heat by conduction.

Figure 14–15 shows how permanent-type insulation is applied to pipe fittings, flanges, and valves. When the piping is 4 inches or more in size, block insulation 1 inch thinner

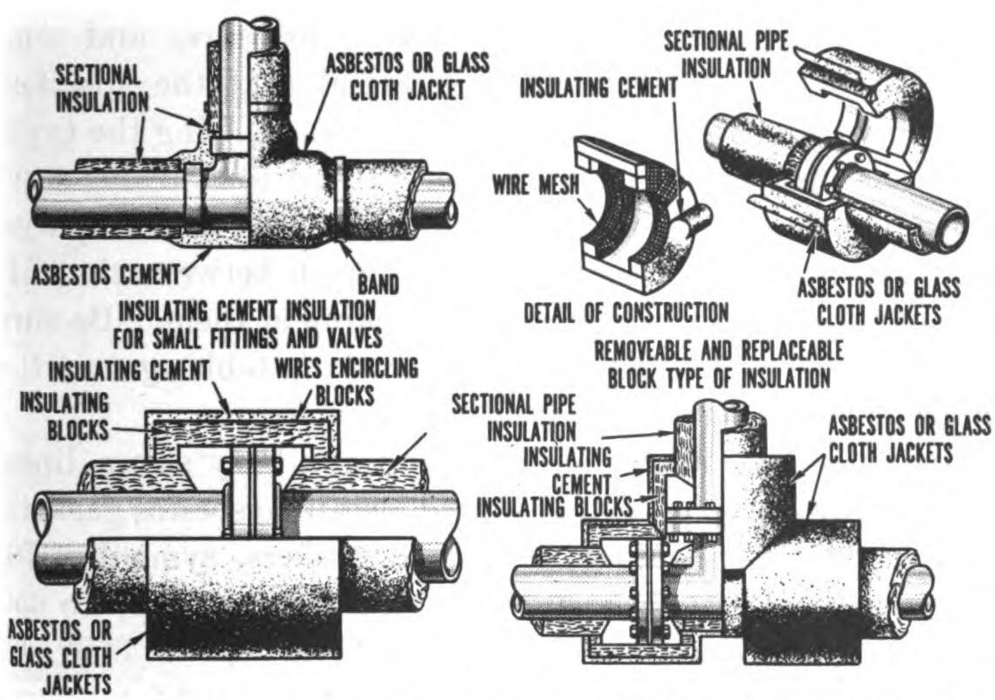


Figure 14–15.—Permanent-type insulation for pipe fittings, flanges, and valves.

than that on the adjacent piping may be used for the bodies of flanged fittings and valves, for the entire surface of a threaded fitting, for the entire surface up to the bonnet of screwed valves, and for the flanges. Insulating cement should be used to make the total thickness of insulation on the valve or fitting equal to that on the adjacent piping. The pipe insulation should be stopped short of the flanges and beveled off, to allow removal of the flange bolts. On piping less than 4 inches in size, the insulation of the fittings may consist entirely of insulating cement, applied to the same thickness as the insulation on the adjacent piping.

Removable-type insulation for pipe fittings, flanges, and valves may consist of asbestos felt pads or sectional pipe insulation of the same thickness as that on adjacent piping. Block insulation ½ inch thinner than that on the adjacent piping may also be used, if it is then covered by ½ inch of insulating cement.

GASKET AND PACKING MATERIALS

The importance of the proper selection of gasket and packing materials cannot be overemphasized. These materials are subjected to widely varying pressures and temperatures, and it is therefore essential that the specified material be used for each service. Tables showing the types of gasket and packing materials approved for various services are posted in the fireroom and in other shipboard spaces.

It is not always possible to distinguish between the different types of packing merely by looking at them. Be sure to check the symbol number on the packing table against the number on the material actually drawn for use.

In replacing gaskets on main and auxiliary steam lines, you will probably use spiral-wound metallic-asbestos gaskets, symbol 2410, or serrated soft iron gaskets, symbol 2470. These materials are approved for steam pressures up to 650 psi and superheater outlet temperatures up to 850° F. High-temperature bolts and nuts of the type used for assembling high-pressure steam valves must be used on steam lines.

Anti-seize compound should be used on the threads of the nuts and bolts, but no compound of any sort should be used on steam line gaskets.

Before a gasket is installed, all seating surfaces must be thoroughly cleaned. They must be checked with a surface plate, and scraped if necessary to give a uniform all-around contact. The procedure for tightening bolts is the same as that previously described for the assembly of high-pressure steam valves.

QUIZ

1. For what temperatures are brass and bronze valves suitable?
2. What material is most commonly used for valves in salt water piping systems?
3. Should globe valves be installed with pressure ABOVE the disk or BELOW the disk?
4. What type of stop valve is commonly used where a straight-line flow of fluid is desired?
5. What type of stop valve works partly like a gate valve and partly like a plug valve?
6. What type of stop valve allows the most precise control of the flow of fluid?
7. What two devices are commonly used to close the port in a check valve?
8. What procedure is used to find out whether or not a valve disk is making good contact with the seat?
9. What method should be used to remove SMALL irregularities from the contact surfaces of the valve seat and the valve disk?
10. If you overgrind a valve seat or disk, how can the error be corrected?
11. What method should be used to correct pitting, scoring, or imperfect seat contact in gate valves?
12. What identifying mark is stamped on the alloy stud bolts and nuts used in assembling high-pressure steam valves and in making up joints in steam lines?
13. In assembling a high-pressure steam valve or in making up a steam line joint, how can you check on the tension required for the final all-round setup on the nuts?
14. What determines the pressure at which a relief valve will lift?
15. In a spring-loaded reducing valve, what two forces determine the position of the controlling diaphragm?
16. What pressure is held constant in a constant-pressure pump governor: the pump discharge pressure, or the pressure of the steam on the discharge side of the governor?
17. What material is most commonly used to insulate high-temperature piping?
18. Why is it important to keep insulating materials free from moisture?
19. What two types of gaskets are most commonly used on high-pressure, high-temperature steam lines?

CHAPTER 15

OIL AND WATER KING

As a Boilerman, you may find yourself assigned to the job of oil king or water king. On large ships, these duties are usually separate, but on small ships they are likely to be combined.

OIL KING

As oil king, you will be responsible for receiving, storing, testing, and accounting for fuel oil. In addition, you will have some responsibility for receiving and accounting for Diesel oil and lubricating oil. In order to perform these duties, you must have a thorough knowledge of your own ship's fuel oil system, including tanks, piping, pumps, valves, cross-connections, manifolds, and all other parts of the system. In addition, you must have a knowledge of fuel oil and its charcteristics; procedures for receiving, storing, and handling oil; methods of ballasting and deballasting; and the requirements concerning oil and water reports.

NAVY FUEL OIL

Two grades of boiler fuel oil are used in steam-powered naval vessels. NAVY SPECIAL FUEL OIL is used in combatant ships. GRADE II FUEL OIL is used in many auxiliary vessels. Navy fuel oils were formerly divided into three classes—Bunker A, Bunker B, and Bunker C. This classification has been discontinued, but you may still hear low-grade oil referred to as "Bunker C oil."

CHEMICAL NATURE OF FUEL OIL

All fuel oil comes from petroleum. Crude petroleum consists of a number of different hydrogen-and-carbon compounds (hydrocarbon compounds) and contains about 84 to 87 percent carbon and 11 to 14 percent hydrogen.

The hydrocarbon compounds in crude oil can be separated into groups of compounds having similar boiling ranges. Each such group is called a FRACTION, and the process by which the various groups of hydrocarbons are separated is called FRACTIONAL DISTILLATION. Fractional distillation of crude oil gives, successively, gas, gasoline, kerosene, Diesel oil, fuel oil, light and heavy lubricating oils, and asphalt.

After the crude oil is separated by fractional distillation, the fractions are usually subjected to certain conversion processes. In the case of fuel oil, the conversion process is known as CRACKING. In this process, the application of high pressures and high temperatures causes a rearrangement of the molecular structure.

FUEL OIL CHARACTERISTICS

Certain characteristics must be known with respect to each consignment of fuel oil. The most important of these are viscosity, flash point, fire point, specific gravity, calorific value, ash content, water content, and sediment content. These characteristics are determined by various tests. Some of the tests are so complicated that they can be performed only in a fully equipped laboratory, but others are relatively simple and can be made on board ship. You should know the purpose of each fuel oil test, and you must know how to perform those tests which are made on your own ship.

Some naval vessels are equipped with an oil testing outfit. This outfit includes a viscosimeter, for determining the viscosity of oil; a flash tester, for determining flash point; a hydrometer, for determining specific gravity; and a centrifuge, for determining the amount of water and sediment in oil.

Viscosity

The viscosity of a liquid is a measure of its resistance to flow. A liquid is said to have high viscosity if it flows sluggishly, like cold molasses; it is said to have low viscosity if it flows freely, like water. The viscosity of oil—and, indeed, of most liquids—is greatly affected by temperature.

Viscosity is usually expressed in terms of the number of seconds required for a given quantity of liquid to flow through an orifice of a certain size, when the liquid is at a certain temperature. The device used to measure this flow is known as a VISCOSIMETER.

The two types of viscosimeters commonly used in the United States are the SAYBOLT FUROL VISCOSIMETER and the SAYBOLT UNIVERSAL VISCOSIMETER. The two are almost identical, except for the size of the orifice through which the sample flows. This orifice is larger in the Furol viscosimeter than it is in the Universal viscosimeter.

In testing the viscosity of a sample of oil, a bath vessel in the viscosimeter is filled with a light grade of lubricating oil. This oil bath is usually heated to the required temperature by an electric heating coil. If electricity is not available, steam may be passed through a U-tube which is immersed in the oil. If it is necessary to cool the oil, cold water may be passed through the U-tube.

The oil to be tested is strained and poured into a tube, where it is heated by the surrounding oil bath. Two thermometers are provided, one to indicate the temperature of the oil sample and the other to indicate the temperature of the oil bath. When the oil sample has reached the required temperature, a cork is pulled from the lower end of the tube and the sample is allowed to flow into a graduated flask. A stop watch is used to determine the number of seconds required for 60 cubic centimeters (cc) of the oil to flow through the orifice into the receiving flask.

The viscosity of the oil is expressed in terms of the number of seconds, the type of viscosimeter, and the temperature. Thus, a fuel oil which, when heated to 122° F, takes 65

seconds to pass through the orifice of a Saybolt Furol viscosimeter has a viscosity of 65 seconds, Saybolt Furol, at 122° F. This is usually written 65 SSF at 122° F.

In the Navy, fuel oil viscosity is generally measured in seconds, Saybolt Furol, while lubricating oil viscosity is measured in seconds, Saybolt Universal. The Saybolt Furol viscosity figure for a given oil is roughly $1/10$ of the figure obtained when the Saybolt Universal instrument is used.

Saybolt Furol viscosities are usually obtained at 122° F. Saybolt Universal viscosities for lube oil are usually obtained at 100°, 130°, or 210° F. When the Saybolt Universal viscosity of a Navy fuel oil is being obtained, the oil should be at 122° F.

Flash Point and Fire Point

The FLASH POINT of an oil is the temperature at which the oil first gives off flammable vapor sufficient to be ignited. The FIRE POINT is the temperature at which its vapors will continue to burn. The fire point may be anywhere from 10° to 70° F above the flash point.

Two types of testers are used for determining flash and fire points. The OPEN CUP TESTER is seldom used for determining flash point, but is always used for determining fire point. Flash point is usually determined by a CLOSED CUP TESTER.

The open cup test is made in a small, uncovered container. The oil sample is heated in this container, and the rate of temperature increase is observed on a thermometer suspended in the oil. Heat should be applied so that the rate of temperature increase is from 9° to 11° F per minute. When this rate of increase has been reached, a lighted taper is passed over the cup, near the oil surface. This operation is repeated at every 5° rise in temperature, until a flash is observed on the surface of the oil. The thermometer is then read, and the temperature at which the flash occurred is noted. This is the FLASH POINT. As more heat is applied to the sample, a point will be reached at which the vapor will remain ignited. The lowest temperature at which this continual burning occurs is noted. This is the FIRE POINT.

When only the flash point is to be determined, the closed cup method is used. The apparatus for this test is shown in figure 15–1. The oil cup rests in a heating jacket. A tightly fitting lid on the cup has an orifice, which can be opened so that a small lighted taper may be placed in the opening.

The oil sample is filtered to remove all water, before being put into the oil cup. The oil cup is filled until it is slightly more than half full, and the cover is closed. While heat is being applied, the oil is stirred continuously by paddles which are operated by a flexible stirring shaft. Heat should be applied so that the rate of temperature increase is approximately 9° to 11° F per minute; when this rate has been reached, and at every 5° increase thereafter, the orifice is opened and the flame is tilted into the cup. As the temperature approaches the expected flash point, the flame is tilted

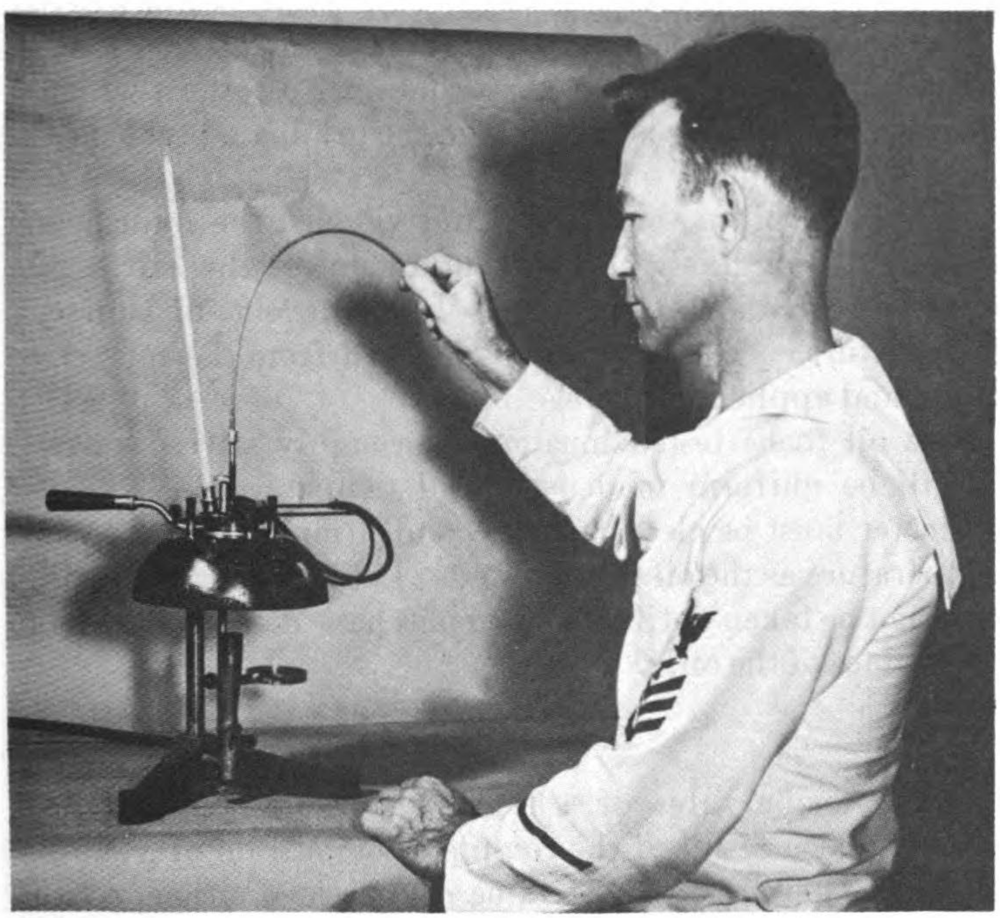


Figure 15–1.—Closed cup apparatus for determining flash point.

into the cup at every 2° F rise in temperature. The flash point is indicated by a flash or slight explosion.

Each oil sample can be used for ONLY one flash test. At the first flash, some of the more volatile vapors are driven off; this reduces the volatility and raises the flash point of the remaining oil.

Specific Gravity

Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water, when both are at 60° F. If the oil is not at 60° F when the determination of specific gravity is made, the figure obtained must be corrected to that temperature by the use of correction tables. (BuShips *Manual*, chapter 40.)

The specific gravity of petroleum products is generally expressed in degrees API, according to a scale developed by the American Petroleum Institute. A hydrometer, graduated in degrees API, is used to determine the specific gravity of fuel oil. A hydrometer is shown in figure 15–2. The instrument is immersed in a glass container of oil, in which it floats. The reading is taken from the graduated scale at the level of the liquid.

When the oil is very heavy and viscous, the hydrometer reading is not likely to be accurate unless the oil is first warmed to reduce its viscosity. In this event, of course, a temperature correction must be obtained from the correction tables and applied to the reading.

The oil to be tested must be thoroughly stirred so that it will be uniform in density and temperature. The hydrometer must be clean and dry, and it must be at the same temperature as the oil being tested. The hydrometer reading must not be taken until all air bubbles have disappeared from the surface of the oil.

Calorific Value

The calorific value of a fuel oil is the amount of heat produced as a result of the complete combustion of a sample of specified size. Calorific value is expressed either in calories or in British thermal units (Btu's). A calorie is the

Figure 15–2.—Hydrometer.

amount of heat required to raise the temperature of one gram of water one degree Centigrade. A Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. One Btu is equal to 252 calories. Calorific value can be measured only by complicated laboratory tests which are not ordinarily made on board ship.

Ash Content

The amount of noncombustible material in a petroleum product is known as ash content. Ash content is determined by laboratory tests which are not ordinarily made on board ship.

Water and Sediment

The oil king is responsible for detecting the presence of water in the fuel oil and—insofar as possible—for preventing contamination of the oil. Fuel oil in the tanks should be tested for the presence of water once each week, and again before the oil is drawn for use.

Before fuel oil is transferred to a fuel oil service tank, or before a service tank is lined up for service pump suction, the tank from which the oil is to be drawn must be checked for the presence of water. About 150 to 300 gallons of oil should be pumped by the stripping system pump, through the low-level suction connection, to the contaminated oil settling tank. During this operation, a sample should be taken through the test connection on the discharge side of the stripping pump. The sample should be examined for the presence of water.

In the sample, water may appear either in emulsion or in a clearly separable form, depending upon the temperature of the oil, the amount of mechanical agitation to which it was subjected, and other factors. If water is present, the stripping must be continued until test samples show that the oil is free of water. If there is any doubt as to the presence of water, a sample of the oil should be tested in the centrifuge.

A centrifuge is a machine which utilizes centrifugal force to separate water and sediment from the oil. A centrifuge

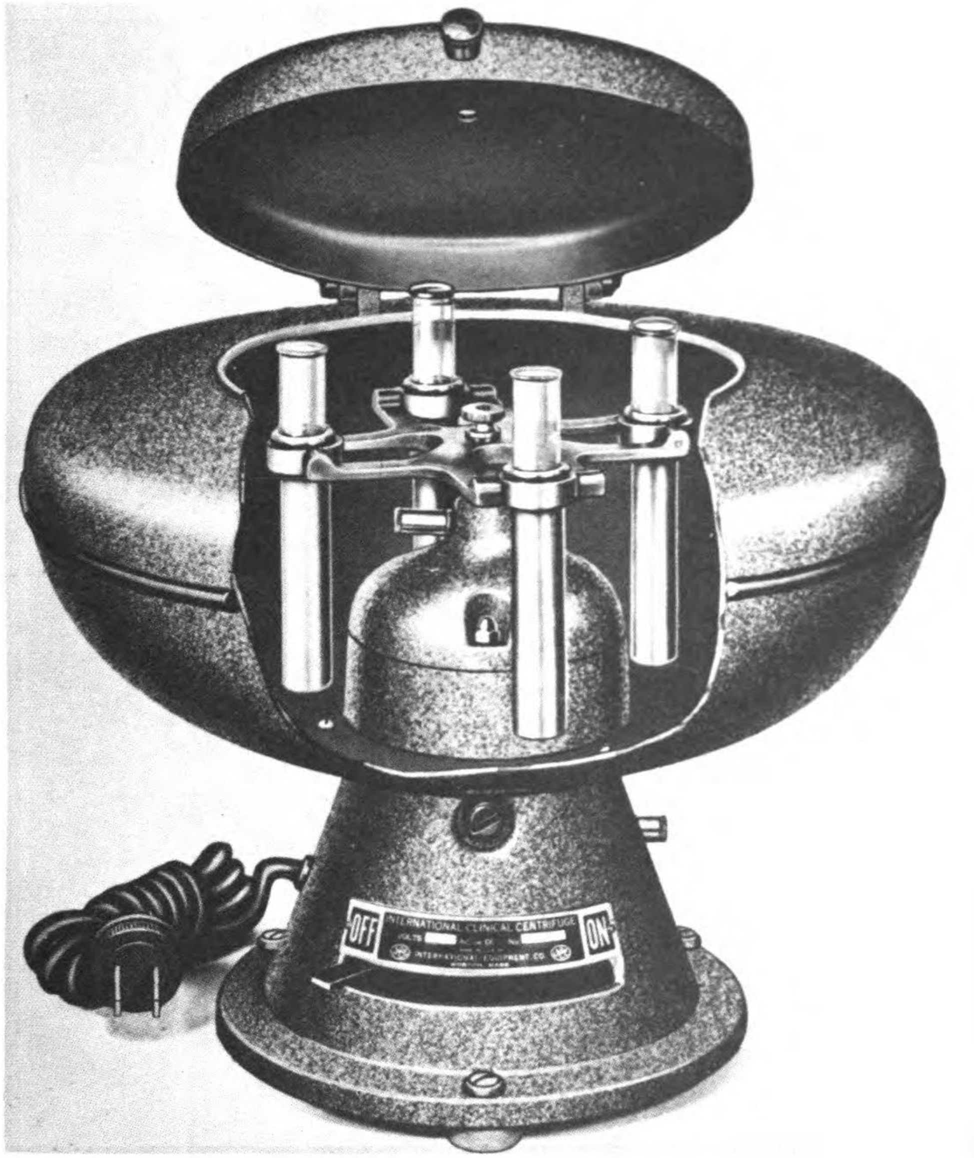


Figure 15–3.—Centrifuge.

is shown in figure 15–3, and a centrifuge tube in figure 15–4.

The oil to be tested is put in the graduated glass tubes. The tubes are placed in the centrifuge in an upright position, in the metal tube carriers. As the top piece is rotated, centrifugal force causes the bottom of the tube carriers to move outward and into a horizontal plane. The water and sediment, being heavier than the oil, are forced to the outer tip (bottom) of the glass tube. When the tubes are removed from the centrifuge, after being whirled for the proper

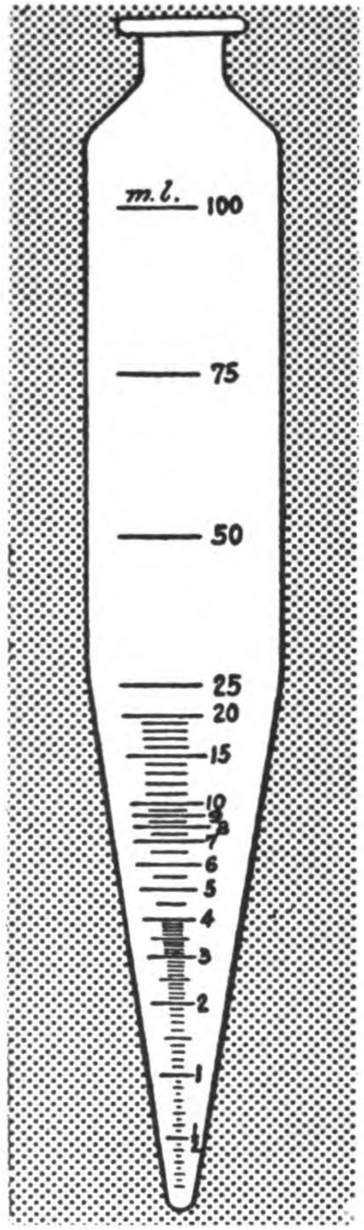


Figure 15–4.—Centrifuge tube.

length of time, all the water and sediment will be at the bottom of the tubes. Since the tubes are graduated, a direct reading of volume of water and sediment may be taken. Centrifuge tubes were formerly marked in cubic centimeters (cc), but will be marked in milliliters (ml) in the future.

Full instructions for using the centrifuge are given in BuShips *Manual*, chapter 55.

Samples of oil from tanks may be obtained either by means

of the test connection on the discharge side of the stripping pump, or by means of a THIEF SAMPLER. Two types of thief samplers are shown in figure 15–5. These may be made up on board ship, or obtained from repair ships, tenders, or shipyards.

Both of the thief samplers shown in the illustration may be used in the standard 1½-inch sounding tubes or in larger openings. The bottle-type sampler on the left side of figure 15–5 is suitable for use where it is not necessary to obtain a sample from the very bottom of the tank. The weight of the bottle is carried on the stopper, so that a quick jerk of the

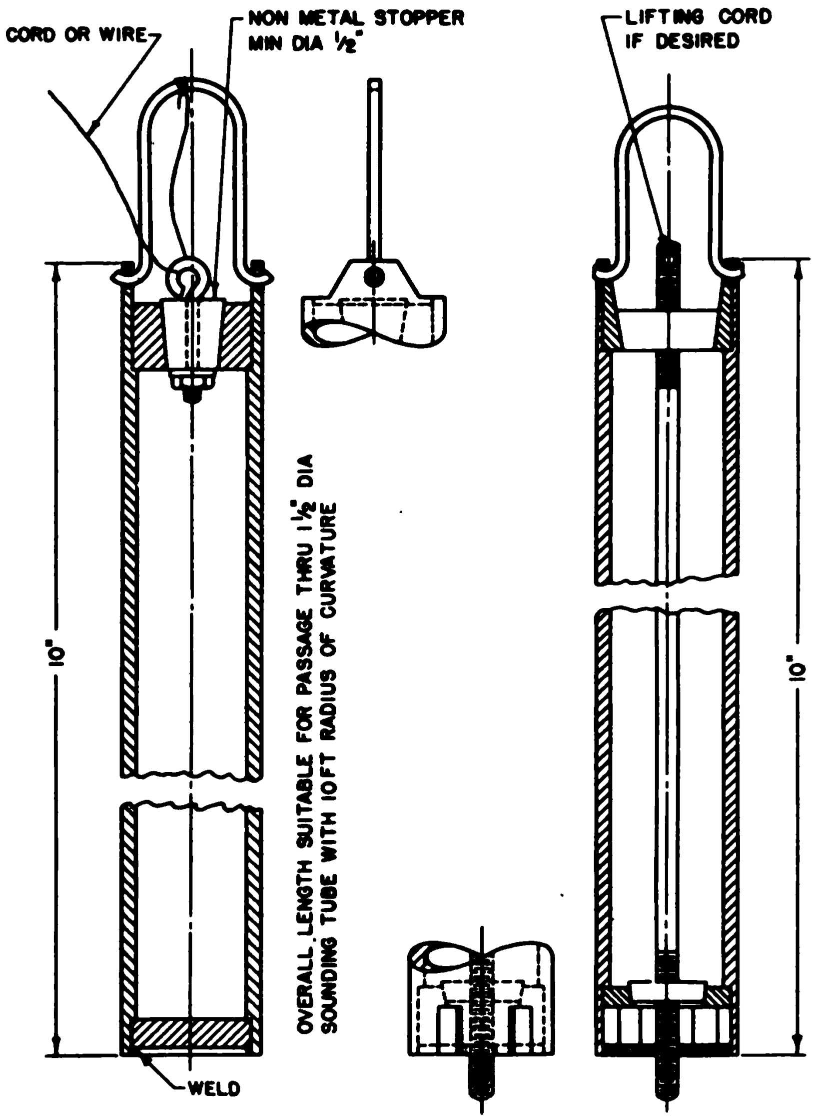


Figure 15–5.—Thief samplers.

cord or wire will remove the stopper. Thus, a sample may be taken at any desired level above the bottom.

The sampler on the right side of figure 15–5 should be used when it is necessary to take samples from the very bottom of the tank. If a pull cord is attached to the valve stem, this sampler may also be used to take samples at other levels.

All thief samplers should be made of nonferrous metal, to reduce the possibility of sparking.

Water-indicating paste is sometimes used on sounding rods in Diesel oil tanks. This paste changes color when in contact with water, and thus indicates not only the presence of water but also the depth of water in the tank. Water-indicating paste is not used in fuel oil tanks, since the fuel oil is so dark that the color of the paste could not be readily seen. The paste can be easily wiped off the sounding rod, and it has no adverse effect on the quality of any kind of oil.

Oil and water mixtures in the contaminated oil settling tanks should be allowed to settle as long as possible before separation of the liquids is attempted. The tank heating coils should be used, since the application of heat causes the oil and water to separate more rapidly. When the water has settled to the bottom, the stripping pump is used to discharge the water overboard, through the low-level suction connection.

After the water has been removed from the tank, samples of the oil remaining should be tested by centrifuge to determine the amount of water in suspension. If the oil is found to be suitable for boiler use, it is drawn from the contaminated oil tank through the high-level suction connection and is discharged into a tank designated for in-port use, or for use at some time when no particular hazard would result from water contamination of the fuel oil.

Every precaution should be taken to prevent contamination of the oil with sea water. Sea water should never be pumped into any tank which contains fuel oil. If the fuel oil should

by accident become contaminated with sea water, the oil should not be burned in the boiler furnace until complete separation has been achieved. Fuel oil which is contaminated with sea water can cause damage to the furnace brickwork, even if the amount of sea water present is so slight that you do not notice any effect at the burners.

FUEL OIL STOWAGE AND HANDLING

Your duties as oil king will make it necessary for you to know where oil is carried on your ship, how these stowage spaces are maintained, and how oil is moved from place to place. Some of this information is given in the chapter on fuel oil systems, and more is given here. It should be emphasized, however, that the best way for you to learn about fuel oil stowage and handling is to study your own ship's system in detail.

Filling Arrangements

A fuel oil tank must not be filled to more than 95 percent of its total capacity. The remaining 5 percent of the space must remain free to allow for expansion of the oil. Be sure that you check the 95 percent level of any tank that you are filling.

Modern combatant ships usually receive fuel oil through a direct pressure connection to the fuel oil transfer system. In these vessels, the tanks are provided with a fuel oil tank overflow system, designed to minimize the possibility of fuel oil being spilled overboard if a tank is overfilled. One overflow system serves a group of adjacent tanks, and is so arranged that overflow from any of these tanks will be led to one particular tank, called the OVERFLOW TANK. During fueling, the overflow tank is not filled until after all the tanks in that group have been topped off to 95 percent of total capacity.

The fuel oil tanks on older vessels are usually filled through deck or side connections which lead to a relay tank. The relay tank is connected by piping to the storage tanks.

The fuel tanks in destroyers are filled through trunks located in the main deck. A port trunk and a starboard trunk are provided for each tank group forward and aft; and an additional pair of filling trunks are provided for the midship tank group installed in later vessels. Fuel oil flows from each trunk to one tank only; the other tanks in the group are filled by means of sluice valves. A 4-inch hose connection on the main deck is connected to the ship's fuel oil transfer system, to allow the discharge of fuel from the vessel; this connection may also be used as a supplementary fueling connection for taking on oil.

Sounding Tubes and Air Escapes

Sounding tubes are perforated at intervals of about six inches, in order to allow oil at any level free access to the interior of the tube. The standard size of sounding tubes is 1½ inches.

Sounding tubes fitted in fuel oil compartments are usually carried to the weather deck. Sounding tubes are fitted with caps or with gate valves to prevent any leakage of oil or vapor. Sounding tubes for oil compartments NEVER terminate in magazines, projectile rooms, or handling rooms.

Air escapes are provided for all fuel oil storage tanks. Air escapes are led to the open weather deck, and are fitted with automatic valves which allow the entrance and exit of air while preventing the entrance of water. Removable flash screens are fitted at the air escape outlet; these screens must be inspected and cleaned at least once each quarter, and renewed if necessary.

When the filling arrangement includes a relay tank, the individual air escapes from the fuel oil compartments lead to the relay tank instead of to the open deck. In this arrangement, the air escapes serve as overflows into the relay tank. A single air escape, fitted with an automatic valve, is led from the relay tank to the weather deck.

Pneumercators and Sounding Rules

Tank level indicating systems of the PNEUMERCATOR type are frequently installed in fuel oil tanks. In this system, a balance chamber in the bottom of the tank communicates by way of a length of tubing with a manometer-type mercury gage. The gage is calibrated to show the depth of the oil in feet. The pneumercator system is described and illustrated in *Fireman*, NavPers 10520–A.

Sounding rules and sounding rods are also used to determine the amount of oil in fuel oil tanks. The rule or rod is lowered to the bottom of a tank, through a sounding tube. Sounding rules and sounding rods are also described in *Fireman.*

Shifting Suction

It is the oil king's duty to make recommendations concerning the particular fuel oil tanks to be used during each 24-hour period. The oil king must be aware at all times of the oil level in the various tanks, and must be prepared to shift suction from tank to tank as required. If possible, the oil king should be present to supervise the shift of suction.

The oil king should be able to give the damage control officer full cooperation if it becomes necessary to shift oil in order to maintain the stability of the ship or to control damage to the hull. The oil king must have an understanding of the effects of free surface, cross-connections between partly filled tanks, and other factors which affect the stability of the ship.

Ballasting and Deballasting

Most combatant vessels now in service are provided with water ballast compensation systems. Such a system allows selected fuel oil tanks to be flooded with sea water in order to provide stability, torpedo protection, and protection from initial list in the event of underwater damage to the ship.

A predetermined plan must be followed so that tanks and voids will be ballasted and deballasted in proper sequence. When one fuel oil storage tank is almost empty, the fuel oil

in it is pumped to another tank and the empty tank is then filled with sea water. The ballasting and deballasting plan specifies the sequence of ballasting and deballasting so that the proper stability will be maintained under all conditions.

Fuel oil tanks should be completely emptied of oil before sea water is admitted. From the Boilerman's point of view, it is perhaps even more important to remember that the tanks must also be completely emptied of sea water before being refilled with fuel oil. If the water is not entirely removed from the tanks prior to refueling, the fuel oil will become contaminated.

Periodic Inspection of Tanks

Whenever a fuel oil tank on any vessel is cleaned and made safe for the entry of personnel, you should take advantage of the opportunity to make a complete inspection of the tank.

On vessels not fitted with a water ballast compensation system, at least one fuel oil tank should be inspected every 18 months. This inspection will normally be made during the ship's regular overhaul at a naval shipyard. The tank designated for this inspection should be one of those in which the most extensive structural deterioration and the largest accumulation of sludge may be expected.

On vessels fitted with a water ballast compensation system, and on vessels in which fuel oil tanks are routinely flooded with salt water, at least 10 percent of the tanks so flooded must be inspected every 18 months—with the exception, however, that no more than four such tanks need to be inspected during any 18-month period. The tanks selected for this inspection should always be the ones which may be expected to be in the worst condition.

Whenever fuel oil tanks are cleaned and inspected, the heating coils must also be tested and inspected.

RECEIVING FUEL OIL

Before receiving fuel oil, you should have soundings taken on all fuel oil storage tanks and all fuel oil service tanks. A statement showing the amount and disposition of fuel oil

presently on board must be submitted to the officer in charge of fueling. It is your job to know how much fuel oil is on hand, where it is, how much can be taken on, where it should be sent, and the order in which the tanks should be filled.

When fuel oil is received from a naval source of supply—that is, a naval vessel, naval storage tank, or naval fuel barge—the activity supplying the oil furnishes the commanding officer of the receiving vessel with an analysis of the oil. If possible, an officer and the oil king should witness soundings and the drawing of samples from the tanks of the supplying activity. The samples must be taken from the suction level of the tank from which the oil is to be taken. One sample should be drawn before loading is started, and another after loading is completed; both samples must be tested by centrifuge to determine the percentage of sediment and water in the fuel oil.

When fueling is accomplished at sea, it may be impossible for the supplying vessel to furnish a complete analysis of the oil, and it may be impracticable for the receiving vessel to send representatives to witness soundings and sampling. In this event, the supplying vessel furnishes a statement of the API gravity and the sediment and water content of the oil. The receiving vessel must then take samples during delivery, and make appropriate tests to determine the percentage of sediment and water. The samples should be taken by dipper from the tank into which the oil is being received, or drawn through connections in the delivery pipe line, when such connections are fitted. Small samples should be taken, and should be accumulated to make a total sample of at least five gallons. Smaller samples for tests can then be taken from the total sample. All containers for taking and accumulating samples must be thoroughly cleaned before being used.

Procedures to be followed when taking oil from commercial suppliers are outlined in BuShips *Manual*, chapter 55.

As fuel is coming aboard, a constant check must be kept on all tanks. When all tanks have been filled to 85 percent of capacity the pumping rate should be reduced and the tanks should be filled more slowly until they are 95 percent full.

When fueling is completed, soundings and pneumercator readings must be taken to determine the amount of oil received. The amount received, the time at which the fueling operation began, and the time at which the operation ended, must be reported to the officer in charge of the fueling. As a rule, an officer and the oil king will then go aboard the supplying vessel to compare the computations of the amount discharged and received. Results of this comparison are reported to the engineering log room, and discrepancies, if any, are noted.

WATER KING

As water king, you will be responsible for storing, testing, and accounting for boiler feed water and potable water. You will not have the job of making fresh water, but you will be responsible for ensuring a continuous supply of boiler feed water and potable water of proper quality.

In order to perform these duties, you must have a thorough knowledge of your ship's fresh water system. This system includes the feed water system and the potable water system. Feed water systems have already been described in chapter 9. You should learn the arrangement of the potable water system on your ship by tracing it out in detail.

As water king, you will be responsible for making tests of feed water and boiler water. The procedure for making these tests has been described in chapters 8 and 9.

OIL AND WATER REPORTS

The oil and water king is responsible for the maintenance of daily fuel oil, Diesel oil, lubricating oil, and fresh water accounts. These accounts may be separate or they may be combined, depending upon the size and type of ship. The reports are submitted to the engineer officer each day during the forenoon watch, and are submitted by the engineer officer to the commanding officer at regular 1200 reports.

The DAILY FUEL OIL REPORT shows the amount of fuel oil on hand, received, discharged, and used during the previous

24-hour period. A typical daily fuel oil report is shown in figure 15–6.

The DAILY DIESEL OIL REPORT is similar to the daily fuel oil report. It contains data on receipts and expenditures of

DAILY FUEL OIL REPORT

U.S.S. Clark Time 2400 Date March 2 1949

TANK	Capacity		Soundings		On Hand
	Full	95%	Feet	Inches	
A-2F	15604	14824	11	9	14824
A-3F	11312	10745	11	5	10745
A-4F	4331	4114	11	5	4114
A-408F	3895	3701	11	5	3701
A-409F	3995	3795	4	4	1785
A-410F	4673	4444	10	8	4144
A-411F	4051	3848	10	9	3848
C-1F	14607	13892	6	6	13892
C-2F	3002	2851	4	3	2002
C-3F	1290	1226	4	4	1226
C-4F	17580	16701	4	3	16701
C-7F	7003	6653	4	4	6653
C-8F	7003	6653	4	4	6653
TOTAL	98346	93447			90288

On hand less received or plus discharged 90288

On hand previous sounding 93447

Expended last 24 hours by sounding 3159

Expended last 24 hours by meter 3167

Expended last 24 hours by pneumercator 3159

Expended underway 2900 Expended not underway 259

C.H. Noble BT2
OIL KING

Figure 15–6.—Daily fuel oil report.

Diesel oil, and on amount on hand. This form is shown in figure 15–7.

The DAILY LUBRICATING OIL REPORT contains an account of all lubricating oil on hand, including all that in the lubricating oil system, in the boat tanks, and stored in cans. A daily lubricating oil report is shown in figure 15–8.

The DAILY WATER RECORD contains information on boiler water, feed water, and potable water. A typical daily water record is shown in figure 15–9.

A FUEL AND WATER REPORT is submitted by the engineer officer to the commanding officer each day at noon. This report is based on the fuel and water reports just described.

The oil and water king should prepare a daily memorandum on fuel oil and makeup feed water, and should see that copies are distributed to engineroom and fireroom personnel. The purpose of this fuel oil and makeup feed memorandum is to inform the engineer officer, the engineering

DAILY REPORT

U.S.S. Clark TIME 2400 DATE March 2 1949

DIESEL OIL

TANK	Capacity		Soundings		On Hand
	Full	95%	Feet	Inches	
C 501 F	7025	6674	4	10	5462
C 502 F	3454	3281	4	6	3231
TOTAL	10479	9954			8693

Received or Discharged 1212

On Hand Less Received or Plus Discharged 7481

On Hand Previous Sounding 9955

Expended 2474

J T Donaldson BT3

OIL KING

Figure 15–7.—Daily Diesel oil report.

officer of the watch, and the petty officers in charge of firerooms and enginerooms as to which tanks are being used for fuel service and makeup feed, and which ones are designated as standby tanks. This information is particularly important to men on watch, since they must know which tanks are available if an emergency requires the shifting of fuel oil or feed water suction. An oil and water king's memorandum is illustrated in figure 15–10.

Safety Precautions

All petroleum products, including fuel oil, are dangerous if not properly handled. Fuel oil vapors are flammable, explosive, and poisonous. The oil king must have a thorough knowledge of the hazards involved in handling fuel oil, and must make sure that all men in his detail observe the neces-

DAILY REPORT

U.S.S. Clark TIME 2400 DATE March 2 1949

LUBRICATING OIL

SYMBOL 2190	100%	95%	Sounding Feet	Inches	On Hand
B-11-Lub	608	577	4	2	576
B-13-Lub	608	577	4	2	577
B-14-Lub	311	295	3	11	195
B-16-Lub	311	295	3	11	295
Lub. Oil System	1211				1211
Motor B. Tank	4				3
In Cases					250
TOTAL	3053	1744			3107
On Hand Prev.	3208				
Expended	101				

F. Harding BT 2
OIL KING

Figure 15–8.—Daily lubricating oil report.

DAILY WATER RECORD

U.S.S. Suarak Time 2400 Date 2 December 1955

BOILERS

No.	Full	St. Level	Cl.	Alk.	Hard.
1	1800	1300	3.5	3.1	0
2	1800	1300	4.2	3.4	0
3	1800	1300	2.6	2.9	0
4	1800	1300	1.4	3.0	0
Total	7200	5200			

FEED WATER

Tank	Full	Soundings		On Hand	Cl.	Hard.
		Feet	Inches			
B-6W	3075	3	9	2005	.09	0
B-8W	3075	3	9	2912	.15	0
B-10W	5010	4	0	5010	.12	0
B-5W	5010	4	0	5010	.08	0
B-7W	4005	3	11	4005	.21	0
B-9W	4005	3	11	4005	.16	0
Total	24180			22947		

Dist. received or discharged	6015
On hand less Dist.	16932
On hand previous sounding	19044
Expended	2112
Expended underway	1880
Expended not underway	232

SHIP'S TANKS

Tank	Full	Soundings		On Hand	Cl.	Hard.
		Feet	Inches			
C-12W	3820	5	11	3820	1.4	1.2
C-13W	3825	5	11	3825	.8	0.9
A-1W	5010	9	6	1001	1.6	0.8
Total	12655			8646		

Dist. received or discharged	4322
On hand less Dist.	4324
On hand previous sounding	12649
Expended	8325
Expended per capita	12

Oil King

Figure 15-9.—Daily water record.

FUEL OIL & MAKEUP FEED DATA — DATE: 24 Aug. '55

Forward Oil Suction	A-408-F
Forward Oil Standby	A-409-F
After Oil Suction	C-8-F
After Oil Standby	C-7-F
Forward Make-up Feed	B-5-W
Forward Make-up Standby	B-6-W
After Make-up Feed	B-9-W
After Make-up Standby	B-10-W

J. J. Jones BT2
OIL KING

Figure 15–10.—Oil and water king's memorandum.

sary precautions. Some of the most important precautions are:

1. Do not allow anyone to smoke or to carry matches or lighters while handling fuel oil.
2. Use only approved types of protected lights when working near fuel oil.
3. Do not allow oil to accumulate in bilges, voids, etc. The vapor from even a small pool of oil could cause an explosion.
4. Never raise the temperature of fuel oil above 120° F in fuel oil tanks; or, if the tanks are next to a magazine, never allow the oil to become hot enough to maintain a temperature of more than 90° F in the magazine.
5. Never raise the temperature of fuel oil above the flash point in any part of the system except between the heaters and the atomizers.
6. Do not allow smoking, or the use of any open flame or any spark-producing objects, in the immediate vicinity of vent pipes from fuel oil tanks.
7. Be sure that the wire screen protectors in the vent pipes are kept intact. Do not allow them to be painted.

8. Remember that fuel oil fumes are poisonous! Signs of poisoning range from eye irritation, headache, and dizziness to unconsciousness and death. A person who is suffering only mild effects may nevertheless cause a serious accident.
9. Do not enter, or allow anyone else to enter, any fuel oil compartment which has not been declared SAFE FOR MEN by the gas-free engineer. Permission must always be obtained before any person is allowed to enter a fuel oil tank.
10. Observe all safety precautions given in section VI, chapter 92, BuShips *Manual*. As oil king, you are responsible for knowing, observing, and enforcing these safety precautions.
11. When your ship is in drydock, be sure that no oil is allowed to drain into the dock.
12. Be sure that you are thoroughly familiar with the provisions of the Oil Pollution Act. A copy of this Act should be posted at any pump which can be used to pump oil overboard.

QUIZ

1. What testing instrument is used to determine the specific gravity of fuel oil?
2. What characteristic of a fluid is a measure of its resistance to flow?
3. What fuel oil testing device is used to determine the amount of water and sediment in a fuel oil sample?
4. At what temperature are Saybolt Furol viscosities usually obtained?
5. What does "40 SSF at 122° F" tell you about a fuel oil sample?
6. In the Navy, what device is used to measure the viscosity of lubricating oil?
7. What is meant by the "fire point" of an oil?
8. How is the specific gravity of fuel oil usually expressed?
9. What term is used to describe the amount of heat produced as a result of the complete combustion of a fuel oil?
10. What pumps are used to transfer oil from storage tanks to contaminated oil or settling tanks?
11. How often should the contents of fuel oil tanks be tested for water?
12. Why are oil system thief samplers made of nonferrous metal?
13. How can separation of oil and water in the contaminated oil tanks be hastened?
14. What percentage of a fuel oil storage tank is designated as expansion space?
15. Where do shipboard fuel oil sounding tubes and air escapes usually terminate?
16. How often must the flash screens in air escapes be cleaned?
17. When refueling at sea, what is the TOTAL amount of oil which must be collected for testing purposes?
18. When does the oil and water king submit the oil and water reports to the engineer officer?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 2

BOILERS

1. It is the heat required to change boiling water into steam at the same temperature as the boiling water.
2. Raised.
3. 335 degrees.
4. Boiler overload capacity is usually 120 percent of boiler full-power capacity.
5. Operating pressure.
6. The end point for combustion, the end point for moisture carry-over, and the end point for water circulation.
7. Only the end point for combustion.
8. The amount of air which can be forced into the furnace.
9. The fact that hot water and steam are less dense than cooler water.
10. Downcomers increase the size of the path for the downward flow of relatively cool water.
11. Accelerated.
12. In a controlled superheat boiler, it is possible to maintain the designed temperature at all speeds, regardless of the volume of steam being generated; also, boilers with superheat control can be designed for higher operating temperatures than boilers without superheat control, given the same quality of materials for piping and turbines.
13. Because auxiliary steam is drawn from the steam drum and does not pass through the superheater.
14. In the economizer, feed water is warmed by hot gases which would otherwise pass up the stack and be lost.
15. Protective steam from another boiler or from some other source is drawn through the superheater until adequate steam pressure has been built up.
16. C-4, left.
17. At a right angle to the drum surface.

18. They increase the heat-transfer surface.
19. To allow for expansion and contraction of the water drum.
20. Grade A.
21. Plastic firebrick and high-temperature castable refractory.
22. Plastic chrome ore.
23. Pumps are used to force the water through the boiler circuits.
24. Since water circulation in a forced circulation boiler does not depend upon a thermally induced flow of water and steam, the units may be arranged more compactly.
25. An amount equal to the amount drawn off in steam.
26. (1) Fire-tube boilers; (2) water-tube natural circulation boilers; and (3) water-tube forced circulation boilers.
27. In Diesel-driven ships only.

CHAPTER 3

BOILER FITTINGS

1. Internal fittings are installed inside the steam and water spaces of the boiler; external fittings are installed outside the steam and water spaces.
2. (1) To minimize interference with the natural circulation of water in the boiler; and (2) to reduce the possibility of setting up metal stresses in the steam drum, such as might occur if the relatively cool feed water came into contact with the hot steam drum.
3. Header-type.
4. Cyclone steam separator.
5. So that the steam will lose some moisture by being forced to change direction before it enters the dry pipe.
6. To prevent leakage from a steaming boiler into the blow piping, or leakage from the blow piping back into a dead boiler.
7. (1) A 10-inch water gage glass; and (2) an 18-inch assembly consisting of two overlapping 10-inch glasses.
8. Before the boiler is cut in on the steam line; at the end of each watch; and whenever there is any question as to the water level in the boiler.
9. The stop valve.
10. (1) Thermal-mechanical; (2) thermal-pneumatic; and (3) thermal-hydraulic.

11. The water level in the steam drum.
12. The relationship between jacket pressure and spring pressure.
13. Between the feed stop and check valves and the economizer.
14. (1) The water level in the steam drum; and (2) the rate of steam flow from the boiler.
15. Swell and shrink.
16. The multi-element regulators compensate for swell and shrink errors, and are therefore more accurate than the single-element regulators.
17. Because the initial lift of the valve disk or feather exposes a larger area for the steam pressure to act upon.
18. By raising or lowering an adjusting ring which shapes the huddling chamber.
19. In order to maintain a steam flow through the superheater.
20. (1) A spring-loaded steam drum valve; (2) a pilot, or actuating, valve; and (3) an actuated, or unloading superheater valve.
21. They are used to clear the boiler firesides of soot deposits, while the boiler is steaming.

CHAPTER 4

CONTROL INSTRUMENTS

1. Compound gage.
2. 74.7 psi.
3. Barometric pressure.
4. 18 inches of mercury vacuum.
5. 5.4 psi.
6. 60.6 inches of mercury absolute.
7. 232.4 psi.
8. A condensate seal must always be maintained between the gage and the steam line, for the protection of the Bourdon tube.
9. It should be adjusted to read correctly at operating pressure.
10. Water-base hydraulic fluid.
11. (1) A bulb; (2) a capillary tube; and (3) a Bourdon-tube type pressure gage.
12. If the readings of two superheater outlet thermometers differ by more than 10° F, the thermometers should be recalibrated.

13. When there is little or no steam flow through the superheater.
14. The difference between superheater inlet pressure and superheater outlet pressure.
15. Because a relatively slight pressure differential is being measured.
16. This arrangement provides a slight constant pressure differential which serves to stabilize the zero reading.
17. Magnetic force.
18. A constant water level is maintained in one chamber; actual water level appears in the other chamber.
19. Because the instrument registers rpm of a rotating shaft as long as it is in contact with the shaft.
20. The stroboscopic tachometer.
21. The Orsat method.

CHAPTER 5

AUXILIARY TURBINES

1. Stage.
2. Only in the nozzles.
3. One simple impulse stage.
4. It is a single-stage velocity-compounded turbine.
5. Curtis stage.
6. (1) By adding extra rows of moving blades, and (2) by directing the steam so that it passes through the blades more than once.
7. A turbine in which two or more simple impulse stages are arranged in sequence in the same casing.
8. It prevents the development of thrust.
9. To maintain the axial position of the shaft.
10. They keep steam from leaking out of the turbine casing at the points where the shaft extends through the casing.
11. (1) Labyrinth packing, and (2) carbon packing.
12. Both the turbine and the driven auxiliary can operate at their most efficient speeds when reduction gears are used.
13. Flexible couplings.
14. When the upper limit of safe operating speed is reached.
15. Flexible couplings, governor linkages, and some governor bearings.

CHAPTER 6

PUMPS

1. Direct-acting.
2. Double-acting.
3. The steam piston is larger in diameter than the pump plunger.
4. It provides automatic timing of the admission and release of steam to and from each end of the steam cylinder.
5. An air chamber and a snifter valve.
6. Because these devices would draw air into the feed water.
7. By causing the pilot valve to block the ports, thus disturbing the admission of steam to the main valve.
8. By moving the tappet collars farther apart.
9. Assemble all pertinent blueprints, drawings, dimensional data, and pump history.
10. The position of the tilting box.
11. The floating ring must be off-center from the pump shaft.
12. A pump which delivers a definite amount of liquid on each stroke or each rotation.
13. One with a relatively small number of teeth.
14. (1) The replaceable inserts take up some of the wear which would otherwise be sustained by the lobes; and (2) they maintain a tight seal between the lobe ends and the casing.
15. (1) The volute pump, and (2) the volute turbine pump.
16. In the volute; or in the volute and in the diffuser.
17. Approximately every 2 months.

CHAPTER 7

FORCED DRAFT BLOWERS

1. Direct-drive steam turbine.
2. From the space between the inner and outer stack casings.
3. Because the lubrication system works ONLY when the blower is rotating in the proper direction.
4. Closed.
5. The centrifugal-type blower sucks air in at the center of the fan and discharges it at the outer edge of the blades; the propeller-type blower moves the air axially.
6. The centrifugal-type blower.

7. To prevent the turbine from overspeeding—NOT to control the turbine at ordinary operating speeds.
8. The centrifugal-weight type speed-limiting governor; and the oil-pressure type speed-limiting governor.
9. An overload nozzle valve.
10. (1) A simple gear pump, on some blowers; and (2) a centrifugal pump, supplemented by a helical-groove viscosity pump, on other blowers.
11. (1) At low speeds, the viscosity pump ensures adequate lubrication of the bearings; (2) at high speeds, the viscosity pump limits the pressure at which oil is delivered to the bearings.
12. When the oil leaving the bearings reaches a temperature of 100° F.
13. Between 140° and 160° F.
14. At least once each watch.
15. Daily.

CHAPTER 8

BOILER WATER TREATMENT

1. (1) Chloride content, (2) hardness, and (3) alkalinity.
2. Equivalents per million (epm).
3. Boiler water should be at ZERO hardness.
4. 2.5 to 3.5 epm.
5. 15 epm.
6. Because the results of the water tests will not be accurate if the equipment is not clean.
7. Below 100° F.
8. The phenolphthalein test.
9. To test the alkalinity of water in freshly filled boilers.
10. 3.4 epm.
11. The lather factor.
12. 0.06 epm.
13. From the BOTTOM of the meniscus.
14. 3.5 pounds.
15. 3.5 epm.

CHAPTER 9

FEED WATER SYSTEMS

1. (1) The condensate system, (2) the boiler feed system, and (3) the fresh water drain system.
2. To condense exhaust steam and deliver the condensate to the boiler feed system.
3. (1) High-pressure drains, (2) low-pressure drains, (3) gravity drains; (4) contaminated drains, and (5) special drains.
4. A reciprocating wet air pump.
5. (1) the wet air pump, and (2) the feed and filter tank.
6. Open, 300 psi or below; semi-closed, 300 to 400 psi; vacuum-closed, 400 to 600 psi; pressure-closed, 600 psi and above.
7. The large amount of vacuum piping required.
8. Only the condensate pump suction lines.
9. Approximately 29 inches of mercury.
10. To be used as cooling water to condense steam.
11. To maintain an adequate supply of cooling water to the air ejector condenser, the gland exhaust condenser, and the vent condenser.
12. Through the condenser.
13. It heats, deaerates, and stores feed water.
14. About 15 psi gage.
15. Equivalents per million, for all tests except dissolved oxygen; parts per million for dissolved oxygen ONLY.
16. 0.5 epm.
17. 0.4 epm.
18. 0.209 epm.
19. 0.5 epm.

CHAPTER 10

FUEL OIL SYSTEMS

1. Fuel oil tanks, piping systems, fuel oil pumps, fuel oil meters, fuel oil heaters, strainers, and fuel oil burners.
2. To transfer fuel oil from storage tanks to service tanks.
3. The micrometer valve on the burner manifold.
4. (1) Storage tanks, (2) service tanks, and (3) settling or contaminated oil tanks.
5. (1) Filling and transfer system, (2) fuel oil service system, (3) stripping system, and (4) ballasting and deballasting system.

6. Stripping system pumps.
7. Keeping the strainers clean.
8. One heater at full capacity.
9. Hourly.
10. Trichloroethylene.
11. Usually between the fuel oil heater and the burner manifold.
12. Once a day, and more often if necessary.
13. (1) Standard nozzles, and (2) semiwide-range nozzles.
14. 200 to 300 psi.
15. (1) The air doors, (2) the diffuser, and (3) the air foils.
16. Wooden sticks.
17. To prevent accumulation of oil on the furnace floor.
18. 350 psi.

CHAPTER 11

FIREROOM OPERATIONS

1. To be sure that they are clean, properly made up, and the right size.
2. To test the emergency feed pump and the feed line.
3. Immediately after the emergency feed pump has been tested.
4. Until the water is just out of sight in the 10-inch gage glass.
5. Ease up on the main steam stop valve stem. (CAUTION: Do NOT lift the valve disk off its seat.)
6. Use the tank heating coils.
7. A small or "port" size sprayer plate.
8. After steam has formed and has blown sufficiently to exclude all air from the boiler.
9. When the boiler pressure is within 100 psi of the reseating pressure of the safety valves.
10. After it is cut in on the auxiliary steam line.
11. To establish a positive flow of steam through the superheater.
12. One or more burners must be in operation on the saturated side, and a positive flow of steam must be established through the superheater.
13. They must be tightly closed.
14. Because the economizer requires a supply of water at all times, to prevent damage from overheating.
15. Before the boiler is cut in on the line; at the end of each watch; and whenever there is any question as to the water level in the boiler.
16. Excess air.

17. By adjustment of the micrometer valve.
18. About 50° F every five minutes.
19. Open it BEFORE the steam flow through the superheater has stopped, and keep it open until the steam drum pressure has dropped to 100 psi or less.

CHAPTER 12

FIREROOM CASUALTY CONTROL

1. To prevent, reduce, or correct the effects of operational or battle damage to a ship's engineering plant.
2. They permit split-plant operation, and permit isolation of damaged portions of the engineering plant.
3. Shut off the oil supply to all burners.
4. Blow the boiler down to the proper level, using the surface blow valve.
5. Secure the main feed pump.
6. Shift the drains to the bilges.
7. (1) Lack of steam flow through the superheater, or (2) failure of the distant-reading thermometer.
8. Rapidly reduce the superheater temperature to a point below the alarm temperature.
9. If the casualty is caused by low water.
10. A flareback.
11. Insufficient air.
12. At least once a month.
13. Cut off the oil supply to the burners and stop the fuel oil pumps
14. The steam smothering system.

CHAPTER 13

BOILER MAINTENANCE AND REPAIR

1. At least once each watch.
2. Twice a day.
3. 600 hours.
4. Dry out the boiler and then spray with metal conditioning compound.
5. To keep the plastic firebrick in place.
6. Whenever the angle of the burner cones differs by more than 5° from the specified angle.

7. The sweep is inserted into the spider ring and into the burne opening.
8. Plastic chrome ore (PCO).
9. PCO must always be installed to its full thickness initially. I must not be applied in layers.
10. Blisters and excessive cracking.
11. To allow moisture to escape and to heal cracks in the refractory
12. Remove the PCO from its container, cut it into small pieces anc allow the material to air-dry for about an hour.
13. 1800 to 2000 hours.
14. The revolving brush will damage the tube if it is allowed tc remain in operation at any one point.
15. A mixture of one part light lube oil and three parts kerosene.
16. A piece of canvas should be stretched across the base of the uptake.
17. Screw the bolts in fingertight; then lightly tighten with a wrench. Work from the center alternately toward each end of the fitting.
18. To prevent combustion gases from backing into the soot blower heads or piping.
19. Because each element is made of metal which is suitable for the temperature to which it will be exposed.
20. To drain off accumulated sludge.
21. To prevent corrosion of the cooler by galvanic action.

CHAPTER 14

VALVES, PIPE FITTINGS, AND PIPING

1. Temperatures up to 550° F.
2. Bronze.
3. Above, except where special conditions require pressure below the disk.
4. Gate valve.
5. Piston valve.
6. Needle valve.
7. (1) A disk, and (2) a ball.
8. Spotting-in.
9. Grinding.
10. Only by machining.
11. Lapping.
12. Either the letter "H" or the letter "A."

13. (1) Use a strain gage, or (2) use a micrometer to measure the elongation of the studs.
14. The tension of the spring.
15. (1) The downward force exerted by the adjusting spring, and (2) the upward force exerted by the reduced-pressure steam.
16. The pump discharge pressure.
17. Magnesia-asbestos pipe covering.
18. Moisture impairs the insulating value of the material, and may cause the material to disintegrate.
19. Spiral-wound metallic-asbestos gaskets (Symbol 2410), and serrated soft iron gaskets (Symbol 2470).

CHAPTER 15

OIL AND WATER KING

1. A hydrometer graduated in degrees API.
2. Viscosity.
3. Centrifuge.
4. 122° F.
5. The fuel oil has a viscosity of 40 seconds Saybolt Furol at 122° F.
6. A Saybolt Universal viscosimeter.
7. The lowest temperature at which the oil will burn continuously.
8. In degrees API.
9. Calorific value.
10. Stripping system pumps.
11. At least once a week, and again before the oil is used.
12. To prevent sparking.
13. By heating the oil.
14. 5 percent.
15. On the weather deck.
16. At least once a quarter.
17. 5 gallons.
18. Each day during the forenoon watch.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

BOILERMEN (BT)

Rating Code No. 4000

General Service Rating

Boilermen operate all types of marine boilers and fireroom machinery; transfer, test, and take inventory of fuels and water; maintain and repair boilers, pumps, and associated machinery.

Emergency Service Ratings

BOILERMEN G (Shipboard Boilermen), Rating Code No. 4001--- **BTG**
Operate and maintain all types of marine boilers and associated machinery; transfer, test, and take inventory of fuel and water.

BOILERMEN R (Boiler Repairmen), Rating Code No. 4002------ **BTR**
Repair and overhaul marine boilers and associated equipment aboard repair ships or at ship repair activities.

Navy Job Classifications and Codes

For specific Navy job classifications included within this rating and the applicable job codes, see *Manual of Enlisted Navy Job Classifications*, NavPers 15105 (Revised), codes BT–4500 to BT–4599.

Qualifications for Advancement in Rating

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
100 PRACTICAL FACTORS			
101 OPERATIONAL			
1. When standing a boiler check watch under way:			
a. Regulate water level in a steaming boiler----	3	3	--
b. Blow down gage glasses------------------	3	3	--

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Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
101 OPERATIONAL—Continued			
c. Detect high- and low-water conditions by observing gage glass and using gage glass blow-down valves	3	3	--
d. Detect signs of oil on surface of water in gage glass	3	3	--
e. Test low-pressure feed water alarms	3	3	--
f. Detect signs of priming and foaming in steam drum	3	3	--
g. Detect and report abnormal feed water conditions to boilerman in charge of fireroom	3	3	--
2. Line up and start forced draft blowers, and check for normal operating conditions	3	3	--
3. Line up and start fuel oil service pump, and check for normal operating conditions	3	3	--
4. Line up fuel oil service pump and stand-by tanks to fuel oil service pumps	3	3	--
5. Shift fuel oil suction and clear fuel oil system of water	3	3	--
6. Regulate forced draft blowers for proper combustion of fuel oil by watching periscope and noting furnace conditions and changes in burner combinations	3	3	--
7. Cut in and secure feed water regulator	3	3	--
8. Regulate fuel oil temperature	3	3	--
9. Light off burners with torch	3	3	--
10. Cut in, cut out, change, and properly assemble burners	3	3	--
11. Regulate oil pressure by use of a micrometer valve	3	3	--
12. Adjust openings of air registers for proper combustion	3	3	--
13. Detect signs of oil in heater drain collection tank, shift drains to bilges, and shift heaters	3	3	--
14. Line up, start, and operate fire and/or bilge pumps to:			
a. Pump bilges	3	3	--
b. Supply water to fire and cooling main	3	3	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
101 OPERATIONAL—Continued			
15. Line up, start, and operate emergency feed pump to:			
a. Feed steaming boilers, using hot or cold feed water suction	3	3	--
b. Fill idle boilers with feed water	3	3	--
c. Add boiler compound to boilers	3	3	--
16. Shift superheater drains from low-pressure (funnel) drains to high-pressure drain main	3	3	--
17. Open root valve, drain, and operate soot blowers for blowing tubes, in proper sequence	3	3	--
18. Sound fuel oil tanks while refueling ship	3	3	--
19. Line up fuel oil system for recirculating and warming up of oil prior to lighting off boilers	3	3	--
20. Test boiler water for content of chloride, alkalinity, and hardness	3	3	--
21. Use calculating charts for determining boiler compound dosage	2	2	--
22. Test boiler feed water for dissolved oxygen content	2	2	--
23. Shift fuel oil service pump from manual operation to pressure regulator control	2	2	--
24. Line up and cut in fuel oil heaters and oil system to burner manifold	2	2	--
25. Use portable tachometer to check speed of fuel oil service pumps and forced draft blowers	2	2	--
26. Line up, start, and operate fire and bilge pump to ballast and de-ballast fuel oil tanks	2	2	--
27. Line up, start, and operate emergency feed pump to transfer feed water	2	2	--
28. Line up, start, and operate fuel oil transfer pump for fuel oil transfer	2	2	--
29. Light off, operate, and secure superheaters on superheat control boilers	2	2	--
30. Split or cross-connect the following engineering systems:			
a. Main steam	1	1	--
b. Auxiliary steam	1	1	--
c. Main feed	1	1	--
d. High- and low-pressure drain	1	1	--
e. Fire main	1	1	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
101 OPERATIONAL—Continued			
30. Split or cross-connect the following engineering systems—Continued			
f. Cooling main	1	1	--
g. Fuel oil suction	1	1	--
h. Auxiliary exhaust main	1	1	--
31. Line up, start, and operate emergency feed pump to hydrostatically test boilers	1	1	--
32. Line up fuel oil system for fueling ship	1	1	--
33. Test fuel oil service, stand-by, and storage tanks for presence of water	1	1	--
34. Empty fuel oil storage tanks and ballast with sea water, using proper sequence	1	1	--
102 MAINTENANCE AND/OR REPAIR			
1. Clean watersides of a boiler, using power-driven tube cleaners	3	3	3
2. Clean boiler firesides, using scrapers, wire brushes, and lances	3	3	3
3. Clean boiler handhole seats and handhole plate seats	3	3	3
4. Spot in, repack, and renew Bonnet gaskets in high-pressure steam valves	3	3	3
5. Replace boiler gage glasses	3	2	3
6. Replace zincs in all fireroom auxiliary machinery equipped with lubricating oil coolers	3	3	3
7. Change lubricating oil in all fireroom auxiliary machinery	3	3	--
8. Spray fireside surfaces with metal conditioning compound	3	3	3
9. Clean and replace parts on smoke indicators	3	3	3
10. Disassemble, clean, and assemble lubricating oil coolers on all fireroom auxiliary machines	3	3	--
11. Locate principal isolation valves in engineering and adjacent spaces	3	3	3
12. Locate and grease boiler sliding feet	3	3	3
13. Clean oil burner atomizers	3	3	3
14. Inspect and clean all strainers	3	3	--
15. Clean and test air register for proper operation	3	3	3
16. Renew weak or broken valve springs on pump end of reciprocating pumps	2	2	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
102 MAINTENANCE AND/OR REPAIR—Continued			
17. Maintain and repair boiler power-driven tube cleaners	2	1	3
18. Read and work from mechanical drawings	2	2	2
19. Dismantle and reassemble boiler internal steam drum fittings	2	2	2
20. Repair burner cone opening, using plastic firebrick	2	1	3
21. Replace small areas in furnace floor and walls, using insulating material and firebrick	2	1	3
22. Make repairs and replacements to gaskets on boiler outer casing panels and doors	2	2	3
23. Repack and replace parts on soot blowers	2	2	3
24. Replace lubricating oil pump parts on all fireroom auxiliary machinery	2	2	--
25. Spot in valve seats and disks on pump end of a reciprocating pump	2	2	--
26. Adjust tappets for proper piston stroke on reciprocating pumps	2	2	--
27. Repack pump end of a reciprocating pump	2	2	--
28. Set all relief valves on fireroom auxiliaries	2	2	--
29. Clean flanges and replace gaskets in main and auxiliary steam lines	2	2	2
30. Spot in slide valve on steam chest of reciprocating pumps	2	2	--
31. Repair and replace parts of forced draft blower shutters and toggle gear	2	2	--
32. Repair insulation and lagging on steam lines	2	2	2
33. Disassemble, repair, or replace parts in high- and low-pressure steam traps	2	2	2
34. Inspect oil burner atomizers for wear and damage	2	2	2
35. Clean firesides of a boiler, using the two methods: Hot-water washing and wet-steam lancing	1	C	1
36. Install handhole plates and tighten or make adjustments as necessary to pass a hydrostatic test	1	1	2
37. Set and test boiler safety valves	1	C	1
38. Test boiler casings for airtightness	1	1	2

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
102 MAINTENANCE AND/OR REPAIR—Continued			
39. Replace thrust and shaft bearings on all fireroom auxiliary machinery, exclusive of electrical equipment	1	C	--
40. Check and set soot blowers for proper blowing arcs	1	C	1
41. Replace chrome ore on boiler stud tubes	1	1	2
42. Disassemble, clean, and replace parts on pump pressure regulators	1	1	--
43. Replace carbon packing rings and oil seal rings in all fireroom auxiliary machinery	1	1	--
44. Replace or plug defective boiler tubes	1	C	1
45. Dismantle, clean, and replace defective parts and reassemble G-fin type of fuel oil heaters	1	1	2
46. Clean fuel oil heaters with chemical equipment	--	--	1
47. Reface main and auxiliary steam line flanges	1	1	1
48. Fit piston rings to steam cylinder of reciprocating pumps	1	1	--
49. Gag safety valves	1	1	1
50. Replace power and idler rotors of positive displacement rotary (fuel oil) pumps	1	C	--
51. Adjust oil burner atomizers with reference to the diffuser plates	1	1	1
52. Disassemble boiler safety valves and inspect and replace defective parts	C	C	1
53. Renew boiler furnace brickwork and insulation	C	--	1
54. Boil out boilers	C	C	C
55. Inspect boiler uptakes and smoke pipes to determine their condition	C	C	C
56. Conduct hydrostatic tests on boilers, and make required inspection for tightness or strength	C	C	C
57. Make detailed inspection of an open boiler to determine material conditions	C	C	C
103 ADMINISTRATIVE AND/OR CLERICAL			
1. Make entries in fireroom operating logs	3	3	--
2. Take charge of fireroom watch in port under auxiliary steaming conditions	2	2	--
3. Make entries in fireroom lighting off and securing sheets	2	2	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
103 ADMINISTRATIVE AND/OR CLERICAL—Con.			
4. Locate and use appropriate sections of BuShips *Manual*, manufacturers' instruction books, mechanical drawings, and handbooks to obtain data when repairing boiler and fireroom machinery	1	1	1
5. Compute and record daily fuel oil and water receipts and expenditures	1	1	--
6. Take charge of a fireroom watch or boiler control station when under way	1	1	--
7. Prepare fireroom entries in daily, weekly, monthly, quarterly, semiannual, and annual check-off lists	C	C	--
8. Prepare boiler record sheets	C	C	C
9. Organize and supervise the work and training of personnel in all phases of operation, maintenance, and repair of marine boilers and auxiliaries	C	C	C
10. Estimate time, labor, and material needed for repair of boiler and fireroom equipment	C	C	C
11. Prepare naval shipyard and tender work requests	C	C	--
12. Organize and assign personnel to fueling stations	C	C	--
13. Order fireroom supplies and materials, using standard stock catalog	C	C	C
14. Supervise fireroom personnel when performing full power and economy runs	C	C	--
200 EXAMINATION SUBJECTS			
201 OPERATIONAL			
1. Safety precautions involved in performing tasks appropriate to applicable rates listed under 100 Practical Factors	--	---	--
2. Procedures to be followed in determining and correcting the following casualties:			
a. Loss of fuel oil suction	3	3	--
b. Loss of feed suction	3	3	--
c. Failure of fuel oil service pump	3	3	--
d. Loss of feed pressure	3	3	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
201 OPERATIONAL—Continued			
2. Procedures to be followed in determining and correcting the following casualties—Con.			
e. Water gage glass carries away on boiler	3	3	--
f. Low water in boiler	3	3	--
g. High water in boiler	3	3	--
h. Class A, B, or C fires	3	3	3
3. Purpose of the economizer	3	3	3
4. Chloride and hardness limits and make-up feed water	3	3	2
5. Types and frequency of boiler and feed water tests	3	3	3
6. Internal and external fittings for naval boilers and the function of each fitting	2	2	2
7. Sources of salt contamination in boiler feed water	2	2	2
8. Characteristics of Diesel, Navy Special Grade 2, and commercial fuel oil. Purpose of each fuel oil test	2	2	--
9. Prescribed rates for raising and lowering superheat temperature on superheat control boilers	2	2	--
10. Conditions which require lifting superheater safety valves by hand	2	2	--
11. Procedures to be followed when superheat thermal alarm sounds	2	2	--
12. Procedures to be followed in determining and correcting the following casualties:			
a. Failure of emergency feed pump to take suction	2	2	--
b. Boiler tube or other pressure part carries away	2	2	--
c. Major fuel oil leak	2	2	--
d. Oil in fuel oil heater drain	2	2	--
e. Water in fuel oil	2	2	--
f. Fire in boiler casing	2	2	--
g. Superheater is lit off and thermometer does not register normal increase in temperature	2	2	--
h. Forced draft blower failure	1	1	--
i. Brick or plastic falls out of furnace wall	1	1	--

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
201 OPERATIONAL—Continued			
12. Procedures to be followed in determining and correcting the following casualties—Con.			
j. Reduction of high salinity in boilers while steaming	1	1	--
k. Lighting off without steam pressure	1	1	--
l. Steaming boiler operating pressure drops below 85 percent	1	1	--
13. Various types of naval boilers	1	1	1
14. Procedures to be followed when using smoke-making atomizers for laying a smoke screen	1	1	--
15. Construction and operating principles of superheater flow indicators	1	1	1
16. Procedures to be followed when spraying metal conditioning compound on boiler firesides	1	1	1
17. Procedures to be followed when superheater or superheat control boilers are lit off and additional boilers are to be cut in	1	1	--
18. Lighting off, operating, and securing procedures on all types of naval boilers	C	C	--
19. Construction and operating principles of all types of boiler and superheater safety valves	C	C	1
20. Inspections to be made preparatory to reporting fireroom ready to answer all bells	C	C	--
202 MAINTENANCE AND/OF REPAIR			
1. Types of power-driven tube cleaners used for cleaning watersides	3	3	3
2. Methods of removing soot from the firesides of a boiler	3	3	3
3. Construction and use of globe, gate, and needle valves	3	3	3
4. Purpose of zincs in salt waterside of lubricating oil coolers	3	3	3
5. Limits of chloride and alkalinity of water in a steaming boiler	3	2	2
6. Effects of low and excessive alkalinity on the watersides of a boiler	2	2	1
7. Selection and use of packing and gasket material	2	2	2

Qualifications for Advancement in Rating	APPLICABLE RATES BT	BTG	BTR
202 MAINTENANCE AND/OR REPAIR—Continued			
8. Types, purposes, and location of boiler furnace refractories	2	1	2
9. Effects of scale on the watersides of a boiler	1	1	1
10. Effects of oil on the watersides of a boiler	1	1	1
11. Methods and procedures to be followed when washing boiler firesides with hot water	1	C	1
12. Factors governing boiler and fireroom machinery efficiency, causes of poor performance, and appropriate remedies	C	C	C
13. Effects of dissolved oxygen on the watersides of a boiler	C	C	C
14. Purpose and procedure for boiler hydrostatic tests, and when conducted	C	C	C
203 ADMINISTRATIVE AND/OR CLERICAL			
1. Use of allowance lists for determining spare parts, tools, and supplies kept on board	C	C	C
2. Procedures for obtaining replacement parts and supplies; maintenance of inventory	C	C	C
3. Reports covering boiler damage and failures that are submitted to BuShips	C	C	C

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